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ABSTRACT

A study was conducted to construct measures of reading competencies that are frequently needed in an occupational environment and to describe the influence of the components of reading practice on these competencies based on the conceptual framework of ethnographic psychology. The reading practices of 25 electrical engineers and 30 electronic technicians were quantified in terms of the number of minutes per month spent reading journal articles, manuals, and schematics. Simulations of reading these materials for general knowledge, specific information and for evaluation purposes were constructed. Results showed that performances on these simulations were moderately correlated for the technicians and uncorrelated for the engineers. Reading practices were independent of each other for both groups. Three out of four specific competencies were predicted from the specific practices that were expected to facilitate them, and these competencies were not associated with other practices that differed in the materials and uses of reading. Six appendixes, which make up nearly half of the document, contain copies of measures used in the study along with related reading materials, most of which are illustrated with diagrams and photographs. Eleven data tables and an extensive reference list are also included. (Author/FL)

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Reading Competencies and Practices

Relationships among Competencies and Practices of Reading

John Guthrie, Irwin Kirsch & Mary An Klein Love

September 1984

Technical Report #7

Final Report

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Relationships among Competencies and Practices of Reading

John T. Guthrie, International Reading Association

Irwin S. Kirsch, Educational Testing Service

Mary An Klein Love, International Reading Association

Table of Contents Page

Rationale..... 2

Literacy in Society..... 2

Readership in the U.S.A..... 4

Reading Competencies..... 5

Psychological and Anthropological Frameworks.....13

Psycholinguistic theory.....13

Discourse processing.....14

Readability formulas.....17

Sociolinguistic analysis.....18

Ethnographic psychology.....20

Objectives of Present Study.....25

Method.....27

Subjects.....27

Development of the Competency Tests.....28

Identification of high volume materials and uses.....28

Strategies used for different practices.....29

Articles for knowledge.....29

Schematics for specific information.....30

Manuals for specific information.....30

Table of Contents (continued) Page

Articles for specific information.....31

Item writing--AKT.....31

Item selection--AKT.....32

Item writing--SSIT.....32

Item selection--SSIT.....33

Item writing--MSIT and ASIT.....33

Item selection--MSIT and ASIT.....33

Description of the Competency Tests.....34

AKT.....34

SSIT.....35

MSIT.....35

ASIT.....36

Reading Practice Inventory (1).....36

Nelson-Denny Reading Test.....38

Administration Procedures.....39

Scheduling.....39

First session.....39

AKT administration.....39

SSIT administration.....41

End of first session.....41

Second session.....42

MSIT and ASIT administration.....42

Nelson-Denny administration.....43

Reading Practice Inventory

(1) administration.....43

Scoring.....44

Table of Contents (continued) Page

AKT.....44

SSIT.....45

MSIT and ASIT.....45

Interrater reliability.....46

Nelson-Denny.....46

Reading Practice Inventory (1).....46

Text Search Process.....47

Results.....49

Occupational Reading Practice.....49

Occupational Reading Competencies.....55

Relationships among Practices and Competencies of Reading.....62

Discussion.....68

References.....72

Tables

Table 1: Reading Practices of Two Occupational Groups

Table 2: Intercorrelation among Uses of Reading

Table 3: Intercorrelations among Materials of Reading

Table 4: Uses and Materials of Occupational Reading in Electrical Science

Table 5: Levels of Reading Competency for Two Occupational Groups

Table 6: Reliabilities of Occupational Reading Competency Tests

Table 7: Intercorrelations among Occupational Reading Competencies

Table of Contents (continued)

Table 8: Levels of Reading Competency for Four Degree Types

Table 9: Intercorrelations for Occupational Reading Competencies and the Nelson-Denny Test for Two Occupational Groups

Table 10: Simple Isomorphic Model of Practices and Competencies: Predictions and Observations

Table 11: Correlations among Practices and Competencies for Simple Isomorphic Model

Appendices

Appendix 1: Articles for Knowledge Test

Appendix 2: Schematics for Specific Information Test

Appendix 3: Manuals for Specific Information Test

Appendix 4: Articles for Specific Information Test

Appendix 5: Reading Practices Inventory (1)

Appendix 6: Text Search Process Form

Abstract

The purposes of this investigation were: (1) to construct measures of reading competencies that are frequently needed in an occupational environment, and (2) to describe the influence of the components of reading practice on these competencies based on the conceptual framework of ethnographic psychology. Reading practices of electrical engineers and electronic technicians were quantified in terms of the number of minutes per month spent reading journal articles, manuals, and schematics for the uses of knowledge, specific information, keeping abreast, and evaluation. Simulations of the reading tasks required to engage in these practices were constructed. Performances on these simulations, termed reading competencies, were moderately correlated for electronic technicians and uncorrelated for engineers. Reading practices were independent of each other for both groups. Three out of four specific competencies were predicted from specific practices that were expected to facilitate them. These competencies were not associated with other practices that differed in the materials and uses of reading. An isomorphic model of competency and practice was relatively well confirmed and is contrasted to traditional formulations.

Rationale

A theoretical orientation to the study of reading practice and competence was delineated in the proposal for the research that has been conducted under the title of "Competencies and Uses of Reading." This orientation not only guided the methodological decisions made during the course of the study, but also sheds light on the findings contained in Technical Reports 1-6 as well as the present results. The orientation of the investigators has not changed substantially, although refinements and extensions have been made possible by published reports and by our findings. The framework for this investigation as it was originally conceived, however, is presented as the rationale for this report to lend a measure of closure to the investigation.

Literacy in Society

> So complete was my father's reliance on the influence of reason over minds of mankind, whenever it is allowed to reach them, that he felt as if all would be gained if the whole population were taught to read, if all sorts of opinions were allowed to be addressed to them by word and in writing, and if by means of suffrage they could nominate a legislature to give effect to the opinions they adopted. (Mill, p. 64)

During the past decade or so, historians and others examining literacy as a cultural phenomenon have attempted to provide an

understanding into how the introduction and evolution of literacy in Western culture might have altered the social, economic, and cognitive characteristics of its members (Goody, 1968; Havelock, 1976; Mcluhan, 1962). Goody and Watt (1968), for example, contend that when a society develops writing, it externalizes its own history, legends, and knowledge. Since the written record is permanent, it is accessible to interpretation and objective thinking. When people are permitted to inspect and read their own history and beliefs, processes of criticism develop. People become less governed by myth and superstition and more persuaded by logical argument and reason. Accordingly, a more scientific and less mythical approach to solving problems and making decisions resulted.

Distinctive properties and uses of written language have become associated with expository prose commonly found in textbooks, encyclopedias, etc. Olson (1975) has suggested that, as a result of the distinct properties and uses of written language, there develops a unique form of logical competency. More generally speaking, schools which place a heavy emphasis on the properties and uses of written language are therefore believed to affect the abilities of people to think logically, make inferences, and classify objects using abstract, rather than concrete, thought processes (Greenfield & Bruner, 1966; Luria, 1976).

Readership in the U.S.A.

In the United States, reading is relatively widespread. In 1929, Gray and Munroe noted that reading was rapidly assuming a place of first importance in modern life. The fact that the sales and distribution of newspapers, magazines, and books were growing at a faster rate than the population was taken to indicate that America was becoming a nation of readers. Bormuth (1978) reported that this trend has continued into recent years. He notes that the numbers of books and pamphlets sold between 1947 and 1972 rose from 6.8 to 8.6 per person; that library circulation increased from 2.47 to 4.17 items per person between 1950 and 1972; and pieces of mail per person increased over the time period from 297 to 418.

While education, occupation, sex, and other variables affect what is read and how much time is spent reading, evidence suggests most people engage in this activity (Gray & Rogers, 1956; Robinson, 1980; Sharon, 1972; Yankelovich, Skelly, & White, 1978). A study conducted by the Educational Testing Service concluded that 95% of American adults can be classified as readers who spend an average of 1 hour 46 minutes engaged in various reading activities each day (Sharon, 1972). With regards to specific reading activities, Sharon reports that over 70% of the population reads a newspaper for an average of 35 minutes each day; 39% spend an average of 33 minutes reading books; 33%

spend an average of 47 minutes reading magazines; and 53% spend approximately 5 minutes each day reading mail.

Of greater significance is the fact that 87% of the persons employed in 1971 reported having to read as part of their jobs. Letters, memos, and notices were among the most frequently reported reading activities. Also included were manuals, forms, schedules, reports, legal documents, and business accounts. The average person reported spending 1 hour each day variously engaged in these activities.

Reading Competencies

Despite indications that reading has become an important factor of modern life interwoven with work, travel, health, citizenship, recreation, and other activities (e.g., Inkeles & Smith, 1974; Waisanen & Kumata, 1972), national attention has been focused on apparent widespread reading difficulties experienced by large numbers of people in this country. Primary support for this concern stems from the results of adult and student performance on several large surveys (Gadway & Wilson, 1975; Louis Harris & Associates, 1970; Murphy, 1973; Northcutt, 1975; Voight, 1973). Based on results from these surveys, it was not uncommon to read or hear the following:

> Item: When given pictures of three competing packagedcereals marked by net weight and price, only three out of four respondents identified the cereal which . . . was the best buy (Northcutt, 1975).

> Item: When shown the picture of a train schedule and asked to circle when a train leaving a given city at a specified time arrives in Washington, only 66% of the sample answered correctly (Murphy, 1973).
>
> Item: Only 62% of the sample, when given a series of newspaper "help wanted" advertisements, were able to correctly match personal characteristics to job requirements. These results produced an estimated 45 million adults who could not perform the task (Northcutt, 1975).

Reviews of the literature in adult reading (Fisher, 1978; Kirsch & Guthrie, 1977-1978) show that estimates of "illiteracy" vary as widely as the measures employed. Depending on how the concept is defined and measured, estimates of "illiteracy" have ranged from 1% to 20% for civilian-noninstitutionalized population. If we accept these surveys as basically accurate, then as many as 50 million adults would appear to have difficulty in utilizing basic written materials. Interestingly, these surveys also indicate that these difficulties are not limited to persons with little or no education--they are prevalent to varying degrees among all groups. As an example, the Adult Performance Level Project (Northcutt, 1975) estimated an illiteracy rate of 11% among professional and managerial workers.

Recently there has been reported concern within the armed services regarding the functional literacy levels of recruits (Sticht & Zapf, 1976). The problem is partly based on the fact that the volume of printed materials supporting military systems has increased substantially. Muller (1976) noted that the pages

of documentation required to support a modern navy aircraft have increased from 2,000 in 1950 to over 260,000 in 1975. More generally, it has been estimated that there exists within the Navy 70 million pages of documentation for operation and maintenance purposes only. Thus, it is expected that while reading demands for jobs will vary, the proportion of time a recruit spends reading will increase, as well as the difficulty of the material, due to the high technology involved (Duffy & Nugent, 1978).

Duffy and Nugent (1978) reported the results of a study to determine the reading skills level of recruits in the Navy. Results from the administration of the Gates-MacGinitie Reading Test to Navy recruits entering between May 13, 1974, and May 30, 1975, indicate that 18.1% are reading below the 8.0 grade level and 25.3% are below the 9.0 grade level. This is particularly significant since the manuals for recruit training and apprenticeship were written at the 11th- and 12th-grade level (Biersner, 1975; Duffy & Nugent, 1978). It is also of interest to note that 2.1% of the sample, or a projected 2,100 men, in the year 1975 had a reading grade level below 4.0.

In 1977, the General Accounting Office sent a report on the need to address illiteracy problems in the military services to the Secretary of Defense. In their report, which is based on literacy research in the Armed Services (Sticht, 1975; Sticht &

Zapf, 1976), the G.A.O. noted that the difficulty to deal effectively with printed materials had deleterious effects on military operations. They noted that poor readers, when compared with the average military populations, tended to:

(1) have higher discharge rates during training--the average cost across services per recruit not completing training is estimated at $2,373;

(2) experience more difficulty in training;

(3) perform less satisfactorily on the job;

(4) lack the potential for and actually are restricted in promotion and career development.

Both civilian and military populations are characterized by apparent widespread reading difficulties. These concerns stem from measures of reading ability and have led to initiation of several strategies to solve the problems. Generally speaking, the Armed Services through its research and development programs, have taken two major approaches to literacy problems: (1) to improve the reading abilities (both general and job specific) of its personnel through training programs; and (2) to produce better, i.e., more comprehensible, materials by reducing the difficulty levels of manuals, texts, etc. The G.A.O. report estimates that $3 million is spent annually to improve individual reading abilities and at least $8 million is spent annually to reduce the difficulty levels of various written materials.

A distinction should be made between an ability-oriented versus a motivation-oriented study of functional literacy. We are proposing an ability-oriented approach that emphasizes the description of different types of abilities and their determinants. A motivation-oriented strategy, although we do not pursue it here, is also promising. This approach requires the identification and description of the perceived causes for failure in reading tasks. Attribution theory (Weiner, 1979) could be employed to examine whether the apparent sources of reading failure are thought to be due to inadequate ability, insufficient effort, high task difficulty, mood fluctuation, bad luck, or lack of support from other people. However, in this study, our goal is to examine determinants of ability to perform reading tasks, rather than the full range of perceived causes or the variables related to motivation for successful accomplishments of tasks.

Measures relating to education, such as years of school completed or grade equivalency scores, have been commonly used to estimate functional literacy levels because they are thought to be indicative of skills which are deemed important by society. While these measures have some utility, they do not yield the kinds of information believed necessary for future educational planning and decision making (Kirsch & Guthrie, 1977-1978).

More recent attempts at measuring literacy have focused on

field-based criteria. As an example, the Adult Performance Level Project (Northcutt, 1975) surveyed agencies, held conferences on adult needs, and conducted interviews with undereducated and underemployed persons to determine the skills and knowledge areas needed for everyday, life-coping tasks. Similarly, the Educational Testing Service conducted a national reading activities survey (Sharon, 1973-1974) to determine representative reading tasks performed by adults in the course of a normal day. This information, in conjunction with feedback by an outside panel of reviewers, was used to develop sets of reading tasks for their National Reading Performance Survey (Murphy, 1973).

In general, these measures, aimed at a more direct, concrete measure of literacy tasks, represent an improvement over more traditional measures in terms of the range of behaviors they include and the types of information they yield. However, close examination reveals that they share many of the same limitations with the more traditional measures (Kirsch, 1978).

Possibly most important among these shortcomings is a lack of theoretical clarification about what is being measured. For the most part, measures of functional literacy have relied on globally stated objectives and test specifications. Common to these measures is the notion that literacy relates to the possession of particular knowledge and skills required to perform specified reading tasks. What is not stated is what these

abilities are.

It has been argued that selecting a representative sample of tasks from a well-defined content domain operationally defines what is being measured and, therefore, is justification for the use of that measure. Guion (1977), for example, stated that, "If the reading comprehension test can be taken by itself as an acceptable operational definition, it is because the behavior sampled has a generally accepted meaning" (p. 6). However, for most reading and literacy tests, this is not the case. To say that a test contains a passage (or document) and a test question does not denote a generally accepted meaning for the demands of the test. The test may make high or low demands on background knowledge, or memory; the answer may not be dependent on the passage (Pyrczak, 1972; Tuinman, 1973-1974); the vocabulary load could determine the performance; the search for the answer may demand a large amount of inference; and so on. As a result, the appropriateness of the test items for measuring reading or literacy cannot be determined only by their content validity.

We have argued (Kirsch & Guthrie, 1980) that to gain an understanding of what a test measures and to responsibly evaluate the responses from that measure depends upon demonstration of its construct validity. This form of validity depends upon the congruence between the stated purposes of the test in terms of cognitive processes, and a description of the relationship

between performance and its demands on these processes.

The concept of literacy (and functional literacy, in particular) pertains both to what people read and the types of information they need to derive from what they read. To specify these requires an understanding of the uses people have for reading (Heath, 1980; Scribner & Cole, 1978). If a certain percentage of individuals successfully complete specified reading tasks, one may infer that these respondents possess certain requisite abilities. However, if the tasks are not performed successfully, it is not clear that abilities are lacking. When people fail to respond to a set of tasks, we have no way of knowing whether the errors are caused by an inability to comprehend the document, the wording of the question, lack of background knowledge, limited uses for reading, all of these factors, or none of them. Whether or not errors are due to cognitive factors, restricted experience, or motivation should affect the interpretation of the score.

The importance of this orientation is noted in the following recommendation by Duffy and Nugent (1978):

> Procedures should be developed to assess the skill required to perform each of the many different kinds of reading tasks found in the Navy. . . . A reading test that assesses a man's ability to deal with the variety of printed materials and the purposes for reading in the Navy is needed to diagnose

specific deficiencies and to determine the effects of job training and job experience on the ability to perform these tasks (p. 25).

Psychological and Anthropological Frameworks

Psycholinguistic theory. One of the more popular frameworks for studying reading has been psycholinguistics. Although word recognition has often been studied under the rubric of perceptual psychology, Gibson and Levin (1975) emphasized that reading words entailed the perception of their graphic, phonological, semantic, and syntactic features. Word recognition in this context has been shown to be influenced by the frequency, pronouncability, imagery, concreteness, and meaningfulness of isolated words (Paivio, 1969; Scarborough, Gerard, & Cortese, 1979). Related to word recognition are processes of decoding in which the printed stimulus is rendered into an oral language-like form. Both accuracy and automaticity of word decoding facilitates fluent reading and semantic processing (Perfetti & Lesgold, 1979). In the field of reading research, vocabulary knowledge, which is construed as both perceptual recognition and extraction of word meanings, has been shown to be highly correlated with a variety of measures of reading comprehension (Anderson & Freebody, 1979). Consequently, the properties of single words cannot be ignored in an account of reading in functional contexts.

Psycholinguistics was profoundly effected by Chomsky's work

which "shifted attention from words, and the associations among them to syntax as a central object of inquiry and a source for organizing principles" (Danks & Glucksberg, 1980). Since then, processing has been shown to be influenced by grammatical transformations (Fillenbaum, 1966) and semantic characteristics of sentences (Clark & Clark, 1968). Logical relations among words or concepts within a sentence influence what is processed and remembered in the sentence as a whole (Pearson, 1974-1975; Warren, Nicholas, & Trabasso, 1979).

Despite the power of psycholinguistic variables in accounting for the perception of words and sentences, the framework is limited by its unit of analysis. As Danks and Glucksberg (1980) point out,

> Just as word recognition cannot be fully understood outside of sentences, sentence comprehension cannot be fully understood outside of larger discourse context. . . . Mechanisms of word and sentence perception are not fully adequate for understanding how larger units, such as conversations and stories are processed. (p. 32)

Rather than words or sentences, a study of functional literacy must take documents, such as memos, manuals, directories, textbooks, catalogs, newspapers, and flow diagrams, as the stimulus material for analysis.

Discourse processing. A second framework for analyzing

functional reading competency is discourse processing. Although some writers may include this under the rubric of psycholinguistics, its emphasis on cognition warrants separate consideration for the present study. From this viewpoint, reading is a cognitive operation which entails information exchange between the reader and the text (Freedle, 1979). The fact that text is a powerful unit of comprehension has been illustrated by studies which show that recall of propositions within text is directly proportional to their importance to the information structure in the text as a whole. This result has appeared both for children (Stein & Glenn, 1979) and for the recall of propositions in scientific texts (Meyer, 1975).

Comprehension of discourse has been shown to be heavily dependent on prior knowledge. Experiments by Bransford and his collaborators (Bransford & Franks, 1971; Bransford & Johnson, 1972) have illustrated that comprehension and recall depend upon background information. For example, the sentence, "Because it ripped, the haystack was important" is grammatically acceptable but seems semantically anomalous unless the context of "parachuting" has been introduced. Both the amount and type of background information controls the amount and organization of free recall of text (Steffensen, Joag-Dev, & Anderson, 1979). Understanding discourse also depends on how inferential processes are used to integrate background knowledge with new information.

Kintsch (1979) claims success in modeling the process of text comprehension by including the variables of: (1) word frequency, (2) proposition density, (3) the number of required inferences, (4) the number of processing cycles for a given text, (5) the number of different arguments in a proposition list for text, and (6) the number of reinstatement searches, which approximates the number of attempts to combine text information with a prior knowledge base. The tested difficulty of samples of discourse and their estimated difficulty from the model correlated at a level of .97. Since word frequency and number of reinstatement searches accounted for most of the variance in this model, we may assume these variables should be pursued in studies of discourse processing.

Despite the advances made in accounting for discourse comprehension, we do not think it is a suitable framework for the present study of functional reading competencies. Many forms of printed material that appear in the natural environment cannot be described as connected prose. Sticht (1980) found that in the armed services, only about 40% of the material used on jobs was classified as discourse; and Mikulecky and Diehl (1979) reported that in several occupational settings, only about 11% of the materials were text in the traditional sense. Consequently, the variables and theoretical systems useful for describing the processing of discourse will not be fully suitable in accounting

for the processing of the full range of documents that are encountered in the occupational or community environment.

Readability formulas. A popular approach to estimating the difficulty of materials is the readability formula. These atheoretical, predictive systems have been summarized by Klare (1974) and usually include an estimate of word difficulty that may be based on frequency or length and an estimate of sentence length that may be based on words, syllables, or highly correlated approximations such as "lexical density." In the armed services, the FORCAST system of Sticht (Sticht & Zapf, 1976) attempted to assign a grade level of reading demand to materials, based on the reading grade level of men who could attain a certain criterion of proficiency in cloze performance on the items. Since the grade level of proficiency of the men could be assessed through standardized tests, materials and individuals could be matched. A major shortcoming of this system is that it is imprecise. Estimates of difficulty for the materials and the reading abilities of the men are often inaccurate, since the background of the reader and particular uses of the documents are not specified in the model.

A problem with readability formulas is that many documents are not accurately represented at the level of the sentence. Since the formulas are limited to word and sentence information, their ability to describe the difficulty of documents is

constrained. Many complex documents, including discourse and other graphic or spatially presented information, are more well construed as a conceptual network (Macdonald-Ross, 1978). It has been shown that one may transform legal or engineering documents to spatial maps which reduce the subjective difficulty of processing. However, algorithms for conducting these transformations have not been developed and published, and although the documents themselves may be transformed, the cognitive operations needed to process them have not been stipulated or experimentally investigated. Since the goals of the reader substantially alter the interaction between the reader and the text (Rothkopf & Koether, 1978), any representation of the document itself will be inadequate in describing its difficulty. A fully accountable system will require descriptions of the reader in terms of language capability and knowledge background, descriptions of the particular uses for the document, and characteristics of the document itself (Kirsch & Guthrie, 1980).

Sociolinguistic analysis. The goal of sociolinguistics is to develop a general theory of the interaction of language and social life (Hymes, 1972). The diversity of speech has been regarded as the hallmark of sociolinguistics and how language is used in different socio-occupational groups has been studied widely (Gumperz & Hymes, 1972). In addition, language in

educational settings acquires variable functions depending on its didactic, conversational, or management uses (Cazden, John-Steiner, & Hymes, 1972). Since the field is basically oriented to the genesis, maintenance, and change of linguistic codes, and reading may be regarded as a written linguistic code, one might expect that sociolinguistics should be a fruitful framework for the analysis of reading competency. However, the thrust of the disciplinary paradigm is oblique to the problem of reading for several reasons. Sociolinguistics has been oriented to speech, including speech communities, conversations, stories spoken by children, and dialogue variation. Although useful research paradigms have been developed (Frake, 1972; Labov, 1972) for understanding language in social contexts, they are appropriate for the public and social qualities of speech, as opposed to the private, personal characteristics of reading. The second factor limiting the sociolinguistic framework as the basis for studying reading competency is that it is the form of language in its variable social context that has been emphasized, as opposed to competence in understanding or using language. Studies of dialect change (Labov, 1972), verbal dueling (Dundes, Leach, & Ozkok, 1972), and rules of address (Ervin-Tripp, 1964) emphasize how the structure of sentences, words, or conversational exchanges vary with the participants, their status, and their intentions (Frake, 1972). Although the study

of reading competency in different occupational and social settings bears a surface resemblance to the study of speech in differing social roles, the covert, receptive characteristics of reading as a language process, and the need to examine a range of environmental contexts including occupational demands and affective needs, as well as social settings, lead to doubts about the immediate applicability of this framework to the present study.

Ethnographic psychology. Since Cronbach (1975) described the need to progress beyond the two disciplines of scientific psychology in 1975, and Bronfenbrenner (1976) urged the concept of ecological validity on educational researchers, methods of naturalistic inquiry have received more attention from behavioral scientists. The term "ethnographic psychology" has been used by the Laboratory of Comparative Human Cognition (University of California, San Diego) to describe an emerging discipline. In the Annual Review of Psychology (1979), the Laboratory stated that this approach

> Seeks to explicate the relation between culturally organized activities and the development of systems of cognitive skills; cognitive universals may be demonstrated and socialization practices certainly control the organization of activities, but a firm understanding of what people are doing, what their activities are is the starting point of

analysis. (p. 164)

Ethnography was coined by Malinowski (1922), who stated with reference to the Argonauts of the Western Pacific that a people should be approached through three avenues.

> The organisation of the tribe, and the anatomy of its culture must be recorded in firm, clear outline. The method of concrete, statistical documentation is the means through which such an outline has to be given. Within this frame, the imponderabilia of actual life, and the type of behaviour have to be filled in. They have to be collected through minute, detailed observations, in the form of some sort of ethnographic diary, made possible by close contact with native life. A collection of ethnographic statements, characteristic narratives, typical utterances, items of folk-lore and magical formulae has to be given as a corpus inscriptionum, as documents of native mentality. . . . The goal is, briefly, to grasp the native's point of view, his relation to life, to realise his vision of his world. (pp. 24-25)

The influences of cultural practice and social structures on the cognitive processes of individuals have been demonstrated in terms of word meanings, lexical hierarchies, syllogistic reasoning, and the development of imagination (Cole & Scribner, 1974; Greenfield & Bruner, 1966; Luria, 1976). For example,

Goody and Watt (1968) contend that literacy increases one's capabilities for logical operation through the detachment of the person from the written material which encourages objective questioning, doubt, and criticism. They suggest that written history which externalizes the past and separates it from the present allows for the redesign of new programs or cognitive systems for the future.

The cultural function of cognitive activities has been shown to condition the proficiency of cognitive processes needed for those activities. Scribner and Cole (1978) reported that cognitive processes that serve to maintain social structures may be highly developed for specific purposes. The acquisition of ability to read and write letters improved a limited range of cognitive skills needed for that form of communication but did not increase reading comprehension generally. Cognitive accomplishments may also be acquired to support occupational needs. Lave (1977) showed that number skills peculiar to tailoring were highly developed in individuals in that occupation. General arithmetic skills were not highly developed; limited transfer and generalization occurred.

An examination of literacy in terms of its sources in occupational, cultural, and personal systems is needed (Havelock, 1980; Resnick & Resnick, 1977). A study by Heath (1980) reported that uses of reading in a community could be described in terms

of seven types: (1) instrumental, which included literacy information about practical problems of daily life, including price tags, checks, bills, advertisements, street signs; (2) social-interactional, which included information pertinent to social relationships, such as greeting cards, bumper stickers, and letters, and recipes; (3) news-related, which included information about third parties or distant events, such as newspaper items, political flyers, and so on; (4) memory-supportive, which included literacy as a memory aid, such as messages on calendars and telephone books; (5) substitutes for oral messages, which consisted of messages left for a parent or a child; (6) provision of a permanent record or historical statements, which included legal records and other institutional statements, such as birth certificates and tax forms; and (7) confirmation, which is writing to support attitudes or ideas already held, including brochures on automobiles and directions for putting equipment together. This inventory of reading uses has many shortcomings and does not meet criteria for classification (Travers, 1980), but it illustrates the need for classification of materials, activities, and functions of reading. Scribner and Cole (1978) said that, "An important research task is finding out what people in various communities and walks of life do with literacy--how they use their knowledge of reading and writing, to what tasks they apply it, and how they

accomplish these tasks" (p. 459). When comprehensive, rigorous taxonomies of reading have been constructed, the stage will be set for examining their acquisition, change, and proficiency.

The framework of ethnographic psychology is heuristic for research on reading or functional literacy, since the description of phenomenon is fundamentally psychological. Reading success requires perceptual, psycholinguistic, cognitive, and affective processes that are adaptable to documents containing connected discourse, technical vocabulary, diagrams, and quantitative systems. The origin and consequences of these processes is partly accountable in terms of the processes themselves and partly in terms of the social, familial, or occupational contexts in which they occur. Cultural, familial, educational, and peer-group values and practices affect performance in two forms, its level of achievement and its likelihood of occurrence in appropriate times and places. This orientation has the characteristics of being: (1) functional, which indicates that it is focused on present, prevalent activities that are adaptive to a social or political structure; (2) cognitive, which indicates that reading is a set of internal processes that are accessible to probes, and that may be inferred from the interaction of person, document, and outcomes; and (3) pragmatic, since the description of existing sources of reading patterns has ecological validity and leads to prescriptions for design of

optimal environments or training programs.

Objectives of Present Study

In previous technical reports, the dimensions of subject matter, content, material type, and use have been shown to describe reading practices. Volume of reading measured in minutes/day has been developed as a sensitive and reliable metric for determining the amount of practice. The first objective of the present study was to examine the association among practices of reading and the influence of job and education on these practices. Within a content domain, what are the correlations among uses and materials and how do these components of practice vary in different occupational categories and educational attainments of individuals?

The second objective was to measure the level of proficiency, or competency, of individuals in the information processing, or reading, tasks that are inherent in the practices identified under the first objective. The objective included describing the intercorrelation of reading competencies and their relationships to the occupational categories and educational characteristics of individuals.

The third objective was to characterize the extent to which the components of reading practice were associated with competencies of reading that seem to be needed to engage in the practices. The expectations of the investigators were based on

an ethnographic psychological framework in which an isomorphic model should be obtained. We supposed that specific competencies would be developed to fulfill the demands of particular practices. The aim was to compare the validity of a general model in which practice and competency are both unitary traits with a specific model in which practice and competency are congruent multidimensional systems.

Method

Subjects

The subjects of the study were employees of a company that manufactures computers and analytical instruments. The population consisted of 30 electronic technicians and 25 electrical engineers.

The recruitment process involved several steps. From the Reading Practices Study (which is described in detail in Kirsch, I. S., & Guthrie, J. T., Reading practices of adults in one high technology company. Technical Report #6, International Reading Association, May 1983), we knew several technicians and engineers. We asked each of them to participate in this present study; all but one agreed. During our first meeting, we asked these people for names of other technicians and engineers who might be willing to participate. We spoke to these recommended people by telephone, explaining the study, its purposes, and who was conducting it. We also ran an advertisement in the company newsletter announcing the study. The subjects received $50.00 each for participating since they did not spend "company time" on this project.

The electronic technicians all had the job title of Electronic Technician and were classified as "Technicians/Skilled". Of the 30, 18 had associate degrees in Electronics (or the equivalent from a technical school or

training program). Ten had received on-the-job training, but had no post-secondary schooling. The other 2 were apprentices who were close to completing the requirements for an associate's degree; each had been with the company less than two years.

The job titles for the second group were diverse, including Materials Engineering Manager, Research and Development Engineer, and Electrical Engineer. Of the 30, 12 had Bachelor's degrees and 10 had Master's degrees in Electrical Engineering. One had the Scottish equivalent of a four year degree, 1 had a bachelor's degree in electrical engineering plus a Master's in another technical field, 2 only had to complete their theses for Master's degrees in electrical engineering. The other four all had advanced degrees in Physics or Chemistry, but their work assignments involved a substantial amount of electrical engineering.

Development of the Competency Tests

Identification of high volume materials and uses.

In the Reading Practices Study (Tech Report 6), the volume of practice for engineers and technicians was described. During the first interview in that study, participants detailed what they read in newspapers, books, magazines and journals, and brief documents, how much time they spent with different contents in those materials, and whether they read the material for work, leisure, school, or some combination. In the second interview, we

selected the highest volume reading activities and probed the respondent about the materials and uses for this reading.

The results indicated that engineers and technicians read journals with high frequency for knowledge, which was defined as reading to increase knowledge for self-improvement or to remember a total body of information. They also read prose, in the form of manuals and journals, and schematics for specific information. We designed four tests to address these materials and uses: Articles for Knowledge Test (AKT), Schematics for Specific Information Test (SSIT), Articles for Specific Information Test (ASIT), and Manuals for Specific Information Test (MSIT).

Strategies used for different practices. Participants in the Reading Practices Study (Tech Report 6) had brought us examples of the materials they read for work, ranging from journals to manuals to schematics, memos and order forms. Sifting through this bulk of material, we selected sample technical journals, electronics manuals and schematics. Nine electronic technicians and engineers who had participated in the Reading Practices Study (Tech Report 6) agreed to meet with us individually to discuss their reading purposes and processes.

Articles for knowledge. The engineers' and technicians' reports led to a simplified scheme on which we based the AKT. According to their descriptions, the typical engineer or

technician approaches a journal wishing to gain knowledge on certain topics. He or she first scans through the table of contents. If a title is intriguing or an author is known, the reader may decide to read the article. At this time, the person formulates several specific questions he or she expects to have answered. The reader may then skim the article to see if it addresses the questions. Upon finding a section that appears to relate to one, the reader may then read more closely. If the section does not answer the question the reader had in mind, the reader may continue to read out of interest, but will probably continue skimming to find the kind of information desired. The reader terminates the process when he finds that the article is not relevant to his needs or that his questions are answered satisfactorily.

Schematics for specific information. The electronic technician or electrical engineer reading schematics for specific information approaches the schematic with a broad base of background knowledge. He recognizes commonly used electronic symbols with ease, for example. If a schematic is unfamiliar, it will be surveyed in terms of its broad structure and operation. When it is more familiar, a particular section of interest is identified and the size, interconnections or functions of a particular component will be identified.

Manuals for specific information. When using a manual to

find a particular piece of information, the reader typically will possess a conscious information goal. He will refer to the table of contents or the index looking for a key word or phrase identical to or related to the goal. If he or she finds a section that appears to deal with the topic, the reader will turn to the section, usually read the second contents table if there is one, and then skim the section looking for the answer. If unable to find the needed information, he or she may return to the table of contents, or check for an index. Paging through the manual looking at the headings was a less efficient strategy that was reported.

Articles for specific information. If the reader knows that desired information is likely to be located in a journal article, he or she often identifies the author, examines the abstract, skims through the introduction, or turns to the end of the article looking for pertinent information. He or she then skims the article looking for relevant headings and reads paragraphs or sections that address the question specifically.

Item writing--AKT. We consulted an engineer to discuss the scheme of reading journal articles for knowledge that we had derived from the discussions. At that time, we asked him to select articles from journals that ETs and EEs would be likely to read and attempt to write questions that would be similar to typical goals of readers. We asked him to write four questions

for each article: Three of the questions should deal with the subject matter of the article but not be answered; a definite section should answer the fourth. The engineer selected 10 articles. Many of the initial questions were too literal and could be answered with a few words. The relevant sections of text were too easily identifiable and these shortcomings were recognized by our collaborator. A revision after a second meeting produced acceptable items that simulated the reading practices of the subject population.

Item selection--AKT. We then asked several ETs and EEs from the Reading Practices Study (Tech Report 6) to take the AKT and offer their opinions and suggestions. As a result of these pilot tests, we eliminated four items. We selected six items that appeared the least ambiguous and avoided unnecessary consumption of time. We scored only five of the six items due to the fact that sufficient information to answer the critical question could be found in more than one location in the article.

Item writing--SSIT. A technician was recruited to draft the SSIT. We located schematics that were similar in size, detail, and function in a variety of occupational settings in this company. The typical kinds of specific information derived from these schematics were discussed with this colloborator. In addition, key symbols and simple diagram conventions were located for inclusion on the measure.

Item selection--SSIT. There were 21 items supplied by the technician. Several individuals who had served as pilot subjects for the AKT took the items. We eliminated some ambiguous, awkward items and some good ones to enable the test to be taken in about 20 minutes. The nine remaining questions dealt with electronics symbols, electronics schematics, and gas chromatograph schematics.

Item writing--MSIT and ASIT. We chose four different manuals for this competency test. Three of the manuals were for equipment manufactured by this company; the fourth was the Logic databook from National Semiconductor Corporation. We wrote questions that were answered in one sentence and could be easily located by using devices such as tables of content, indexes, secondary contents tables, and chapter headings. We constructed a total of 16 questions over manuals.

Using journals supplied as samples of job-related reading (Electronic Design, EDN, and Materials Engineer) by technicians and engineers during the Reading Practices Study (Tech Report 6), we wrote questions requiring literal information. As a rule, the answers could have been underlined in a sentence; the testtaker could formulate an answer in a few words. Originally, we selected 16 articles and wrote one question for each.

Item selection--MSIT and ASIT. Participants from the Reading Practices Study (Tech Report 6) took items from this test on a

trial basis. To enable the tests for both articles--specific information and manuals--specific information to be completed in one hour a total of 16 items was desirable. From the original item set the easiest were deleted. Attempting to maximize diversity, we arrived at a total of eight questions from the manuals and eight for journal articles. Allowing four minutes for search time for each question produced a maximum time for the two tests of 64 minutes. During the scoring process one item was dropped from the MSIT because a misleading phrase in the question led to frequent misconceptions by the subjects. The deletion of this question brought the total of manual-related questions to 7.

Description of the Competency Tests

AKT. This test contained 6 items. (See Appendix 1 for sample items.) Each item consisted of four questions and a journal article. The articles were taken from two technical design journals: Electronic Design and EDN. They ranged in length from about 2,400 words to 8,000 words. The articles were removed from the actual journal, so the subject was reading the article along with advertisements, author information, illustrations, charts, and tables. The four questions all dealt with the topic of the article, but only one was fully answered.

Subjects were instructed to read and remember the questions and then to skim the article looking for the specific section that answered one of the questions. The subject was permitted to

refer to the questions at any time. Upon finding the section, the subjects were instructed to point it out to the examiner who then recorded the time spent searching. If the subject pointed to the wrong section, the examiner provided feedback and the subjects continued searching. After 7 minutes, if the subject was unable to locate the correct section, the examiner directed him to the proper location. Once the section was identified, the subject had up to 5 minutes to read the section closely enough to answer the question in writing without referring to the article. The subject was told not to worry about phrasing, spelling, or style. The first item was designated a practice item.

SSIT. The nine items on this test examined the experise of subjects at extracting information from electronics design drawings. Several questions referred to schematics for gas chromatographs. No time limit was given for this section. Knowledge of symbols and relationships among symbols was needed to locate the specific information required by the questions. Answers were written by the subject in a few words. (See Appendix 2 for the test and answer key.)

MSIT. Two questions were written over each of four different manuals. Three of the manuals were for equipment manufactured by the company; the fourth was the Logic databook from the National Semiconductor Corporation which lists circuitry parts and data information on these parts. Subjects read the question, received

the actual manual, and were told to find the answer in any way they wanted. All of the manuals had tables of content and two had indexes. Two had secondary contents tables before each chapter. Subjects were allowed four minutes for each question. They wrote answers on an answer sheet which permitted only a short answer of a sentence or less. (See Appendix 3 for sample items.)

ASIT. Eight questions covered 8 separate articles taken from Electronic Design, EDN, and Materials Engineer. Articles were detached from the magazine, revealing advertisements, author information, tables, and illustrations. Each item consisting of a question and an item was presented individually. The time required to locate the answer as well as the accuracy was recorded for each item. The questions were constructed to contain words or a phrase that was included in the relevant section heading in the article or the topic sentence of the relevant paragraph. (See Appendix 4 for sample items.)

Reading Practice Inventory (1)

We based the Reading Practice Inventory (1) on the Inventory from the Reading Practices Study (Tech Report 6). The survey from that study required two sessions of about one and a half hours each. We constructed a condensed version that would take no more than 20 minutes. The shortened form asked the subject to estimate time spent reading journals, schematics, and manuals for

the uses of knowledge, specific information, evaluation, and keeping abreast. We defined these purposes for this study as:

KNOWLEDGE--you read to increase knowledge and to remember a total body of information. For example, you might read an article carefully to understand the causes of inflation and unemployment.

SPECIFIC INFORMATION--you are looking for information embedded in large amounts of print or for a piece of information to satisfy a particular need. Locating the time for the office picnic in a memo is an example.

KEEPING ABREAST—you read to become aware of new ideas, facts, or developments, to learn the gist of topics, to keep up in a field. Looking over an article on the Presidential candidates' campaigning is an example.

EVALUATION--you read to examine and judge written material or to detect errors in, correct, or revise a document. An example is reading a proposal in order to review it and give a formal response about its content.

The survey consisted of a total of 24 questions--2 questions for each type of material coupled with a purpose. The first question in each set asked respondents to estimate how many times a month or week they read the specific material (journals, schematics or manuals) for a particular purpose (knowledge, specific information, keeping abreast, or evaluation). The second

question asked how much time, ranging from one minute to an hour or more, they spent whenever they read such material. For example, in asking about journal reading for knowledge, the questions read:

> How often do you read about electronics and engineering in journals and technical magazines for the purpose of gaining knowledge?
>
> When you do read about electronics and engineering in this material to gain knowledge, how much time do you spend with it?

This series of questions allowed us to categorize the subjects' reading into 12 different reading practices: the Articles for Knowledge Practice (AKP), the Articles for Specific Information Practice (ASIP), the Articles for Evaluation Practice (AEP), the Articles for Keeping Abreast Practice (AKAP), the Schematics for Knowledge Practice (SKP), Schematics for Specific Information Practice (SSIP), the Schematics for Evaluation Practice (SEP), the Schematics for Keeping Abreast Practice (SKAP), the Manuals for Knowledge Practice (MKP), Manuals for Specific Information Practice (MSIP), the Manuals for Evaluation Practice (MEP), and the Manuals for Keeping Abreast Practice (MKAP). (See Appendix 5).

Nelson-Denny Reading Test

To compare performance on the occupational reading

competencies in this study with a traditional measure of reading comprehension, the comprehension subtest of Form E of the Nelson-Denny Reading Test was included. The comprehension test takes 20 minutes. It contains 8 passages, each followed by several multiple choice questions. The 36 questions are split evenly between those asking for literal information and those asking for interpretation.

Administration Procedures

Scheduling. When asking subjects to participate in the study, we told them to expect that their time involvement would amount to about 3 1/2 hours, the first session to last about 2 hours, the second 1 1/2 hours. All sessions were to be conducted individually; that is, one examiner would be meeting with one participant at a time. Once the person agreed to join the study, an appointment was made for the first session with one of two examiners. The sessions were held in the company library, which was relatively free from distraction.

First session. Participants either met the examiner at the reception area or came directly to the library. After introducing herself and providing some background information about the study, the examiner then asked the subject for his job title, the number of years in the job, the type of degree he held, and when the degree was earned. Once the subject appeared at ease, the examiner began the testing session.

AKT administration. The examiner began by handing the subject typed instructions for the AKT (see Appendix 1). To ensure that each participant approached the test with the same orientation, the examiner read the instructions aloud to each person.

After the subject understood the directions, the examiner handed him the first set of questions and repeated the instruction to read and remember the four questions. When the subject indicated he was ready, the examiner handed him the article and started a stopwatch.

If the subject found a section that he thought answered one of the questions, he showed the examiner the section and told her what question he thought it answered. If it was the correct section and question, the examiner wrote down the total time spent searching, marked a plus sign (to indicate a successful search) on a record sheet and reset the stopwatch. The subject then had five minutes to read the section carefully enough to write an answer to the question without referring to the article.

If the subject chose a wrong section or question, the examiner told him that another section answered a question more completely. In the event that he was unable to locate the section after seven minutes, the examiner showed him the section and told him what question it addressed. At that point, she marked on the record sheet that the subject had spent seven

minutes searching and a minus sign indicating an unsuccessful search. She reset the stopwatch, telling the subject to read the section in order to answer the question.

After the subject read the section and returned the article, the examiner noted how much of the maximum of five minutes had been used and repeated the instruction that the answer should be brief and the subject should not worry about sentence structure, style, or spelling. Occasionally, a subject spent a great deal of time formulating answers in addition to using the maximum time for searching and reading. When the time limit of one and a half hours was exceeded, we stopped the AKT after the fourth item and scored the last item incorrect.

SSIT administration. The SSIT was conducted immediately after the AKT was completed. The procedure for this test was: The examiner handed the subject the test, 4 schematics, and an answer sheet. No time limit was set, but most people were able to finish the test in 20 minutes.

End of first session. After the SSIT was completed, the examiner and subject scheduled an appointment for the second session. The examiner repeated that this session would last approximately an hour and a half and that she would have a check for the subject at this time. All subjects who took the AKT and SSIT agreed to return for the second session and did, in fact, complete the study.

Second session. The second session, scheduled for one or two weeks after the first meeting, was conducted individually, again in the library. Usually the examiner was the same person who had conducted the first session, but scheduling difficulties occasionally necessitated that the second session be conducted by the other of the two examiners.

MSIT and ASIT administration. At the beginning of the second session, the examiner gave the subject an answer sheet containing spaces for 16 short answers (a sentence or less) and a copy of the test. (The MSIT and ASIT were administered together: The questions for the MSIT and ASIT were on the same paper and the answers were written on the same answer sheet.) The instructions were: Find the answers in any way you can and write them on the answer sheet. The subject was allowed four minutes for each question. After the subject read the first question, the examiner handed him the first manual.

Each manual had two questions. The examiner handed the subject each manual after he had read the first of the two questions associated with it. In a similar manner, the subject was handed each of the eight journal articles after reading the question that accompanied it.

During the time the subject was searching for the answers, the examiner was noting the process on the Text Search Process form in Appendix 6. When the subject wrote down the answer, the

examiner noted the time spent searching. If after 4 minutes the subject was unable to locate the answer, the examiner identified it, but no answer was written on the answer sheet. After each item the examiner asked the subject whether he had previously read the article or manual. With both the manuals and the journal articles, the individual was generally able to say yes or no to this question without hesitation. When a question arose, the examiner specified that a "yes" response indicated that the respondent was positive that he had previously read that exact manual or article.

Nelson-Denny administration. The Nelson-Denny was given immediately after the completion of the MSIT and ASIT. The examiners read standard instructions to each subject. The test was stopped after 20 minutes as instructed in the administration manual.

Reading Practice Inventory (1) administration. After the completion of the Nelson-Denny test, the examiner handed the subject the Reading Practice Orientation (see Appendix 5). The examiner read the orienting instructions aloud to the subject, informing the subject that the activity was designed to estimate the amount of time per month that he spent reading about electronics or engineering in journals, schematics, and manuals for certain purposes. The subject was told that any length of time from one minute to an hour or longer should be reported and

that reading did not have to be confined to a specific location. The definitions of the four uses were read to the subject.

As the respondent answered each question, the examiner coded the response according to frequency and time. If a response seemed high or low to the examiner, she probed the respondent for more detail to confirm or revise the report. This section of the session usually lasted 10 to 20 minutes.

Scoring

AKT. We reviewed the AKT and the comments made by technicians and engineers while taking it. The engineers had consistently singled out one item as being answered throughout the article and not confined to a specific section. We made the preliminary decision to drop this item from consideration, and consultants confirmed this as appropriate.

The engineers who had served previously as pilot subjects assisted in devising prototype answers. They identified key words and phrases that they felt must be included in correct answers to each item. For question 1, they identified 3 necessary factors; question 2, 4 necessary factors; question 3, 3 necessary factors, question 4, 3 necessary factors; question 5, 1 necessary factor.

After reviewing the answers agreed upon by the consultants and the researchers, we decided upon a scoring system for each of the tests. For the AKT, a score of 10 was possible, that is, the

highest score an answer could receive was 2. If an answer mentioned 0 factors, the score was 0. For questions requiring 3 necessary factors (i.e., questions 1, 4, and 5), an answer containing 2 or 3 factors was to be scored a 2, an answer containing 1 factor would receive a 1. For question 2, which required 4 necessary factors, an answer containing 2, 3 or 4 factors was to be scored a 2, an answer containing 1 factor would receive a 1. Question 6, which required only one factor, was scored either a 2 or a 0. Since one question had been eliminated, this scoring scheme allowed the perfect score of 10.

SSIT. With this test, the consultants confirmed the previously identified objective answers for 5 questions, and provided us with key phrases for the other 4.

The highest possible score for the SSIT was 27. For each of the 9 questions, a score of 3 was given if the answer was perfect, a score of 1 if the answer contained at least one of the required parts of the answer, and a score of 0 if the answer was completely wrong.

MSIT and ASIT. With both the MSIT and the ASIT we examined each question with the consultants. Both confirmed that the questions were sound from an engineer's and technician's viewpoint and that the answers that were previously obtained were accurate.

Each correct answer was scored 1 for both the MSIT and the

ASIT. Since we had dropped a question from consideration on the MSIT, a high score of 7 was possible. For the ASIT, a perfect score equaled 8.

Interrater reliability. Two scorers were provided with the prototype answers for the AKT, the answer keys for the SSIT, MSIT, and the ASIT, and the scoring information for all of the competency tests. Each scorer corrected the same four tests separately. A comparison of their results revealed 100% agreement on the SSIT, the ASIT, and the MSIT. The interrater reliability on the AKT was 94%; however, the disagreement was only with one question. After discussion with the consultants, this disagreement was resolved.

Nelson-Denny. The Nelson-Denny was scored according to the examiner's manual. A raw score of 72 was possible, and this score could be converted percentile ranks. We decided to convert the raw scores to percentile ranks given by the publishers for the end of sophomore year in college.

Reading Practice Inventory (1). The first part of the scoring of the RPI(1) was completed at the time of administration. When a respondent estimated the frequency of a reading practice, the examiner coded the response according to the following: A response of "never" was equal to 0; "one to three times a month" was scored as 1; "weekly" was scored as 2; "2 to 4 times a week" as 3; and "5 or more times a week" as 4.

The examiner coded the estimate of time by the respondent as follows: 1 to 4 minutes was coded 6; 10 to 14 minutes was coded as 7; 15 to 29 minutes was coded as 8; 30 to 60 minutes was coded as 9. Any length of time over an hour the examiner specified.

The next step was converting these estimates to minutes per month for each practice. We took the average or midpoint for the coded responses. That is, the midpoint of "one to three times a month" is twice a month; "weekly" is 4 times a month; "2 to 4 times a week," 12 times a month (3 times a week times 4 weeks a month); and "5 or more times a week," 20 times a month. The midpoint of 1 to 4 minutes is 2; 10 to 14 minutes, 12 minutes; 15 to 29 minutes, 22 minutes; 30 to 60 minutes, 45 minutes. When the frequency per month estimate is multiplied by the time estimate the minutes per month (M/M) is obtained.

Thus, a coded response of "1, 5" equals 4 minutes per month for that particular reading practice: 2 (times a month) times 2 (minutes per occurrence). Minutes per month spent reading were obtained for each reading practice.

Text Search Process

Additional data were gathered during the administration of the MSIT and the ASIT that are not reported as results. While the individual was searching the manual or journal for the answer, the examiner noted on the form displayed in Appendix 6 the process he or she was going through. Without interrupting

the examinee, she watched as he turned pages, checked indexes or contents tables, flipped through text, or read more attentively. The examiner numbered the events as each occurred. A person who spent the whole four minutes searching, for example, may have checked the table of contents four or five times. This was indicated, as was the order in which he did so.

The purpose of this observation system is provide the basis for the development of a cognitive process model that may account for competency in this form of reading.

Results

In the Reading Practices Study (Technical Report #6,) practices of reading were delineated in terms of contents, materials, and uses of reading activities. In the present study, a sample of each dimension was selected for measurement and for comparison to the reading competencies that may be needed to engage in those practices. Although the settings in the Reading Practices Study (Technical Report #6,) included both occupational and leisure, setting was restricted to occupational in this investigation. The contents consisted of electrical science and electronics, a part of the natural history category examined previously. The material category was restrained to schematics and two forms of prose, that appearing in journal articles and manuals. The uses consisted of knowledge, specific information, keeping abreast, and evaluation. Although keeping abreast and evaluation were not included in the simulation tasks that were constructed to measure competencies, they were included in the assessment of reading practice to improve the accuracy of measuring the volume of reading for different purposes. Because the content of reading practice measured in this study was, in all cases, electronic, that dimension will not be contained in the descriptions of this section.

Occupational Reading Practice

Reading practice was quantified in terms of number of minutes

per month. This metric derived from aggregations described in the method section. The volume of reading practice for the group of Electronic Technicians (ET) was 1,666 minutes per month (m/m), and the volume for Electrical Engineers (EE) was 2,016 m/m. See Table 1. These totals may be subdivided according to materials and uses. The ET group read articles 452 m/m, schematics 588 m/m, and manuals 626 m/m. The EE group read articles 890 m/m, schematics 581 m/m, and manuals 545 m/m. The principal distinction between the groups, at this descriptive level, is volume of reading of articles.

The uses for reading differed slightly for the groups, though analysis of variance reported later in the Results shows this to be an insignificant interaction. The ET group read for knowledge 649 m/m, specific information 611 m/m, keeping abreast 208 m/m, and evaluation 198 m/m. The comparable figures for the EE group were knowledge 623 m/m, specific information 478 m/m, keeping abreast 526 m/m, and evaluation 390 m/m.

To what extent are practices of reading associated? The conceptual framework of ethnographic psychology presented briefly in the introduction suggests that reading activity is adaptive to its particular social and occupational environment and, therefore, practices will be relatively independent. This suggestion may be examined by referring to the intercorrelations among practices. For this study, the components of practice

consisting of use and material were examined separately.

The intercorrelations among uses of reading for all types of materials for both ET and EE groups are presented in the top portion of Table 2. A total of five out of six uses did not correlate significantly higher than zero. The association of knowledge and keeping abreast, however, was .22 ($p < .05$). This pattern was duplicated for articles and schematics. An exception to it appeared for manuals. Different uses were associated significantly in four cases out of six, indicating that individuals who read manuals frequently for one use, or purpose, tended to read them for other purposes, and people who read them little for one purpose read them little for any.

With the important exception of manuals and with the total data set in mind, it may be suggested that uses for reading are not highly associated. That is, a person cannot be construed as a "heavy" reader or a "light" reader, a high volume or low volume reader. The one who reads for the purpose of specific information may or may not read for knowledge or evaluation. The predictability is nil within the constraints of the investigation. It will be more advisable apparently to describe a person in terms of the particular constellation of uses that is exhibited or reported by that individual.

The material component of practices of reading may be treated in similar terms. How highly are materials associated? As

depicted in the top portion of Table 3, none of the correlations among articles, schematics, and manuals was significantly different from zero. A highly repeatable pattern of non-significant correlations is obtained when the separate uses are examined. The amount of time spent reading articles is not highly associated with the amount of time spent reading schematics or manuals. A person, then, cannot easily be defined as a reader or non-reader, a high or low volume reader, based on volume of one type of material alone. All three types of material are needed for an accurate construction of the reading practices of a person.

To analyze the extent to which the volume of reading practice was influenced by the educational attainments of the individuals in the study, a 4 (degrees) X 3 (materials) X 4 (uses) analysis of variance was conducted. The first factor was between-subjects. This analysis also examined the effect of components of practice (material and use) on volume of reading practice. Significant main effects were not observed for educational attainments (degrees) or material. Use had a significant main effect ($F = 3.01$, $p < .03$, df = 3/42). Further, a significant interaction between material and purpose was obtained ($F = 4.04$, $p < .001$, df = 6/42). The other interactions were not significant.

The relationships among uses and materials are shown in Table

4. The interaction may be interpreted in terms of how the uses vary for the three categories of materials. Articles from journals were used primarily for keeping abreast (296 m/m) and also for gaining knowledge (220 m/m). Schematics were used primarily for locating specific information (289 m/m), but some volume of evaluation (156 m/m) also occurred. The last column in Table 4 shows that manuals were used mainly for knowledge acquisition (300 m/m) and moderately for specific information (217 m/m). Therefore, both the primary and the secondary uses for these categories of documents were distinctive. It should be noted that each material was used substantially for more than one purpose. The notion that one material may have one use, such as "manuals are used to locate facts and specific information" must yield to a more complex account of the utilization of documents.

The relationships of reading practices and occupational categories was examined with a 2 (jobs) X 3 (materials) X 4 (uses) analysis of variance with repeated measures on the latter two factors. It is valuable to note that occupational category, i.e., ET vs. EE, did not have a significant effect on volume of reading practice. The factor of material had no significant main effect. Uses exhibited the same main effect that it did in the analysis of variance described in the previous paragraph ($\underline{F}$ = 3.00, $\underline{p} < .03$, df = 3/53). Likewise, the identical interaction of materials and purpose emerged ($\underline{F}$ = 6.29, $\underline{p} < .001$, df = 6/53),

but the other 2-factor interactions were not significant.

From this analysis of variance, the 3-factor interaction of occupation X material X use was found to be significant (F = 2.67, $p < .01$, df = 6/53). This finding is important since it confirms the expectation drawn from ethnographic psychology that specific practices would be adapted to specific occupational functions. This interaction may be understood by first recalling the interaction of material and use for the total group. As presented in Table 4, the highest volume of use for articles was keeping abreast; schematics were used for specific information, and manuals were used for knowledge acquisition. This interaction, however, varied for the two occupational groups. The pattern can be seen in Table 1. For the ET group, articles were used primarily for knowledge rather than keeping abreast, which prevailed for the EE as well as the total. The ET group read schematics for the use of specific information which contrasted with the EE group that used schematics for evaluation. The ET group and the EE group both read manuals mostly for knowledge although this trend was more pronounced for the technicians than the engineers.

Since the significant interaction in this analysis was 3-factor rather than merely 2-factor, a valuable step forward in understanding reading in occupational contexts can be made. Not only are certain categories of materials prevalent for certain

jobs, but particular uses for those materials are also prevalent in those jobs. A psychological account of the human information processing activities that occur frequently in practical settings, such as a high technology corporation, may benefit from data on how the goals of individuals are engaged with written documents to accomplish objectives held by the larger group of workers or managers.

Occupational Reading Competencies

The competencies of individuals to perform occupational reading tasks that are needed for their practices were measured. The assessments consisted of simulations of the tasks performed in the occupational setting. The simulation contained samples of actual material that appeared in the workplace and the most frequently occurring uses that were reported for those materials. The levels of proficiency attained in these simulations were mixed. Some were high, whereas others appeared to be moderate.

The test that was devised to measure how adequately people gained knowledge from journals in electronics contained five tasks as described in the Method section. The results from these tasks are presented in Table 5. The first phase of the knowledge from articles tasks was a measure of the time to locate the section in the text containing the answer to one of the four questions presented in association with the task. The ET group

required 28.6 minutes, whereas the EE group required 26.6 minutes for the total of five tasks. Within the allotted time, the ET group had a mean of 2.1 and the EE group had a mean of 3.0 in accuracy of locating the correct section in these five tasks. Next, the ET group required 16.2 minutes to read the correct portions of the text, and the EE group required 14.0 minutes. Finally, the ET group attained a mean of 4.6 points and the EE obtained 7.4 points out of 10 possible points given for the accuracy of their answers to the questions.

The other competencies were measured more simply than knowledge from articles. The test on specific information from schematics contained nine items and a total of 27 points was awarded. The ET group had a mean of 16.6 points and the EE group had a mean of 22.6 points. This appears to be a marked superiority for the engineers. The competency of locating specific information from articles was exhibited at similar levels. The ET group had 5.0 and the EE group had 6.0 correct out of eight items. The competency of obtaining specific information from manuals was exercised with relatively high facility. That is, on the test of seven items, the ET group had a mean of 5.0, and the EE had a mean of 6.1 items correct. As percentages of the total possible, these means are relatively high, indicating superior accomplishment in this competency by both groups.

Prior to presenting correlational and inferential statistics, the reliabilities of these measures will be given. As shown in Table 6, the internal consistency of the four measures of accuracy on gaining knowledge from articles, specific information from schematics, specific information from articles, and specific information from manuals was computed. Reliabilities indicated by Cronbach's alpha were .71, .87, .52, and .37 respectively. When these are adjusted to estimate their reliabilities if about 30 items were written for each test, the reliabilities increase to .94, .95, .81, and .70 respectively. With the exception of manuals--specific information which is moderate, these reliabilities are high enough to indicate that stabile competencies were assessed and to permit reasonably sensitive comparisons among them.

The correlations among the competency tests are presented in Table 7. For the total group, the correlations ranged from .52 to .71. These are significantly higher than zero ($p < .01$), and their levels are substantial but not remarkably high. For the ET group the correlations follow the pattern for the total group. Consistent association appears between .51 and .72. Despite the reduction in group size, these are all significantly higher than zero ($p < .01$).

For the EE group, however, the correlations were uniformly low. They ranged from -.18 to .31 and none was significantly

different from zero. It is incumbent on an investigator to determine whether this low level of association is due to a statistical artifact or whether it accurately describes a population that is to be distinguished from the ET group. The low association cannot be attributed to low reliabilities since their adequacy has been discussed previously. It is possible that the variance in the test scores for the EE group is restricted and prevents a possible correlation from appearing. This restriction could be due to ceiling effects in which engineers get a large percentage of all the items correct. An inspection of the distribution of scores from the EE groups on each of the four competencies showed that a ceiling effect and a resulting skewed distribution did not appear, with the possible exception of the manuals test in which 8 of 25 individuals attained perfect scores. More convincing is the fact that each of the competency tests correlates at a statistically significant and substantial level with at least one other measure on the study. The knowledge from articles correlated with the Nelson-Denny Percentile Rank for the EE group at .41 ($p < .05$); the specific information from articles correlated with the Nelson-Denny Test at .52 ($p < .01$). The specific information from schematics test correlated with the practice of reading schematics for specific information at .45 ($p < .05$); and the specific information from manuals test was associated with the

total practice, i.e., total amount of time spent reading, at .34 ($p < .05$). Since each of the competencies of the EE group are correlated with at least one other variable, they must not be insensitive due to a lack of variance within each one. A more plausible explanation for the low correlations is that this group is distinct from the ET group. That is, competencies among the ETs are predictable from each other; whereas, competencies among the EEs are substantially independent.

The effect of education on competency level was analyzed with a 4 (degree) X 4 (competency) analysis of variance with repeated measures on the competency factor. For this analysis, the accuracy scores on the four competency tests in Table 8 were employed. The results were that degree had a significant main effect ($F = 19.73$, $p < .001$, df = 3/42). In all cases, except one, groups with higher degrees had at least slightly higher competencies. See Table 8. The factor of competency was significant ($F = 336.36$, $p < .001$, df = 3/42), which resulted from the fact that the tests were different lengths. The interaction of degrees and competency was significant ($F = 12.89$, $p < .001$, df = 9/42), which warrants further interpretation. Generally, the differences between degrees varied according to which competency is examined. Pronounced effects appeared for knowledge from articles and specific information from schematics, but limited effects were seen for the other two measures.

The effect of degree of education was also assessed on the time-based competency measures. In this case, a 4 (degrees) X 3 (competency) repeated-measures analysis of variance was used. The results were negligible. Neither degree nor the interaction were significant. The competency factor was significant (F = 152.60, $p < .001$, df = 2/42), reflecting that the nature of the tasks allowed substantially different total scores to be obtained.

The relationship of occupational category to competency was measured with a 2 (jobs) X 4 (competencies) repeated-measures analysis of variance using the accuracy scores. The results contained significant effects for both job (F = 17.70, $p < .001$, df = 1/53) and competency (284.30, $p < .001$, 3/53). The job effect confirmed that engineers were generally higher than technicians; and the competency effect again reflected the differences in test length.

The interaction between jobs and competencies was also highly significant (F = 8.07, $p < .001$, df = 3/53). This result may be interpreted by inspecting Table 5. It is apparent that the ET group is lower than the EE group on knowledge from articles with means of 4.6 and 7.4 respectively. The ET is also lower than EE on gaining specific information from schematics with means of 16.6 and 22.6. Whereas these discrepancies appear to be substantial, the difference between the groups on the specific information from articles is minor, 5.0 vs. 6.0; and the distance

between them on specific information from manuals is equally small, 5.0 and 6.1 respectively. Although the engineers are superior on two of the measures of reading competency, the technicians were equal, or insignificantly lower, on the other two accuracy measures of reading competency that were conducted.

The analysis to determine the effect of job on the time-based competency measures consisted of a 2 (jobs) X 3 (competencies) repeated-measure analysis of variance. The measures were: (1) time to search for the section in the knowledge from articles task; (2) time to read the section in the knowledge from articles task; and (3) time to search for the answers in the specific information from articles and specific information from manuals tests combined. The time data for the latter were not segregated for separate analysis. The results were a significant effect for job ($\underline{F} = 9.61$, $\underline{p} < .003$, df = 1/53), a significant effect for competency ($\underline{F} = 167.62$, $\underline{p} < .001$, df = 2/53). The interaction was not significant.

The relationships of the Nelson-Denny reading comprehension section to these reading competency measures is shown in Table 9. The mean of the ET group in terms of the Nelson-Denny Percentile Range (NDPR) was 32.0 and the mean for the engineers was 71.5 for the end of sophomore year college norms. For the ET group, the correlations were consistently low moderate, ranging from .31 to .54 ($\underline{p} < .05$). For the EE group, the knowledge from

articles correlated with NDPR at .41 and .52. The other two measures, however, were not significantly associated with NDPR. These moderate associations imply that an academically oriented reading test like the Nelson-Denny promises weak predictions about job-relevant reading competencies. Certain occupational reading tasks such as searching journal articles for specific information are predicted by Nelson-Denny reasonably well. The other competencies in information processing through reading such as reading manuals are not well estimated by the Nelson-Denny. For purposes of decisions about individuals or groups and for purposes of studying reading in context, simulations of occupation reading will be superior to standardized, traditional reading comprehension tests.

Relationships among Practices and Competencies of Reading

The present study has been addressed to the issue of the extent to which competencies of reading are developed by individuals to be commensurate with the practices of reading that occur in substantial volumes for those individuals. A test of this expectation may be conducted by comparing the predicted and observed correlations among reading practices and competencies. The model surmises that a specific practice consisting of a unique combination of content, material, and use will be correlated with performance on tasks that simulate the actual practice. That is, a person who invests a relatively large

amount of time in reading a particular content-material-use combination will be relatively proficient in tests that are good simulations, i.e., tests that require the same cognitive processes as the practices themselves. The model predicts non-zero correlations between the volume of a specific practice and the degree of competency exhibited on a simulation test of that practice. Likewise, zero-level correlations are expected to appear between practices and competencies that do not share all the components of content, material, and use. This model may be termed isomorphic to underscore the parallelism in form and structure of the practice and competency.

The data from this study were compared to predictions and reported in Table 10. In this depiction, the plus signs (+) show that a prediction from the model was confirmed by the data. Confirmation may have occurred in two forms. A significant positive correlation that was predicted and observed was awarded a +. The same designation (+) was given if a non-significant correlation was expected and such a result was obtained. Disconfirmations of the model may have taken the form of a predicted correlation that was not observed or an observed correlation that was not predicted.

The number and proportion of confirmations of the model was reasonably high. Expressed as a percentage, the number of confirmations, compared to the total number of predictions, was

84%. That is, 37 predictions were correct out of a possible 44. This pattern suggests that the levels of specific reading competencies are associated with the volume of practice in which that particular competency is exercised. For example, the competency of gaining knowledge from articles was positively correlated with the amount of time spent reading articles for the use of gaining knowledge. This competency was not, however, predicted by nine other reading practices within the identical content of electronics. It must be conceded that one disconfirmation in the model occurred in which proficiency in gaining knowledge from articles was positively predicted by the practice of gaining knowledge from manuals. Evidence for an explanation of this exception is not immediately forthcoming.

The disconfirmations consist mainly of positive correlations that were not expected in the model. Exactly 50% of these positive correlations were found between the volume of reading articles for knowledge and the three competencies of schematics--specific information, articles--specific information, and manuals--specific information. These associations are sensible since engaging in the activities of reading articles for knowledge is likely to make the individual knowledgeable in the content of electronics, which in turn will facilitate the performance on most reading tasks within this subject matter domain. One of the confirmations requires further discussion.

The correlation between the competency in reading articles for specific information and the practice of the same description was significantly associated but in a negative direction. This indicates that individuals who showed high levels of proficiency on this test reported spending a relatively small amount of time in this activity. It is plausible that people who are effective in locating information are quick in performing the process and do not report spending a large amount of time in it. The data, however, do not support this notion. The correlation between competency of specific information in journals and the amount of time spent locating information in the competency test in which the materials of journals and manuals were combined was .12, which did not differ from zero. An alternative explanation is that those individuals who are relatively low in this competency do not have sufficient knowledge of the content domain and the macrostructure of articles in this area to enable them to retrieve and recall information efficiently. Therefore, they are obliged to spend a substantial amount of time performing the practices to meet their information needs. A test of knowledge administered in conjunction with the other measures is needed to pursue this hypothesis.

The relationship between practice and competency for the two occupational categories may be described by examining Tables 1 and 5 simultaneously. It can be observed that the two groups are

different from each other in the two competencies of knowledge from articles and specific information from schematics. The EE group surpasses the ET in both. In the first competency, the EE group has a substantially higher volume of relevant practice than the ET group. This sustains a simple effect of facilitation of competency by practice. The second competency, schematics for specific information, shows a more complex pattern. The EE group has lower volume of the related practice than the ET group, i.e., 341 m/m, 221 m/m, respectively. However, the EE group has a very sizable superiority in volume of practice on another use--evaluation--for this material. It may be important that evaluation is more a complex cognitive process than locating specific information. Extended practice in the more complex use may enable the EE group to exceed the ET group in locating information in those schematic materials. This hypothesis warrants further empirical investigation.

The two competencies of locating specific information in articles and in manuals were similar for the two groups. The analyses of variance support the contention that the differences between the groups on these tests were significantly smaller than the differences between them on the other tests. The practices of reading follow the same pattern. That is, the differences in volume between the ET and EE groups were significantly smaller than the other practices. The actual means are 42 m/m and 52 m/m

for the ET and EE on specific information from articles; and 227 m/m and 205 m/m for ET and EE on specific information from manuals. Therefore, on competencies for which the groups were similar, despite the large contrast in Nelson-Denny scores, the practices were also similar in type and volume. On competencies for which the EE group was superior to ET, the former group reported substantially higher volume of practice in the identical or more complex practice.

Discussion

Relationships between reading competency and reading practice were the topic of this study. There are two conceptual frameworks within which these aspects of reading may be viewed. One of these has been termed the traditional psychometric perspective. In this orientation, reading is a relatively homogeneous, cognitive process that is gradually acquired in school and may be measured with one homogeneous test. At most, the test will have two sections, vocabulary and comprehension, but these are often correlated highly. This reading ability is applied by the individual in a variety of situations where it may be beneficial, the perspective suggests. The practices, or activities of reading, are determined by the individual's topical interests, e.g., fiction or popular mechanics. The relationship between practice and ability is assumed to be relatively low, with the exception that an individual with absolutely no reading skill cannot at the same time be an avid literary consumer.

An alternative model of the connection between practice and competence is proposed by the framework of ethnographic psychology. This orientation begins with any setting in which a person may choose to engage in reading. This setting may be a school, home, military, occupational, or community situation. The individual is immersed in a plethora of social, linguistic, and cognitive forces. Some of these induce the person to seek

written language. The enormity of these pressures, and their dimensions of internal-external, social-cognitive, obligatory-free, and so on, cannot be fully elaborated in this space. The intention of the person, however, within a milieu is the starting point of the reading act. The intention leads the person to select a type of material, such as a magazine article, textbook, or table on a certain subject matter such as foreign trade deficits, nutrition, or electronics. The person then plays out his or her intention with regard to the substantive material. The intention may be fulfilled or not, but its termination vis-a-vis the particular materials and content ends the reading event.

A person with an extensive, recurring activity that combines intention-material-content may be said to be engaging in a reading practice. Notice that the term practice is not used in the sense of "repeated efforts to improve," but in the sense of "adaptive, consciously intended, cognitive-affective processing that yields valued benefits." The individual who is characterized as having an extensive practice of reading will undoubtedly be quite specific in the use (intention), material, and content of that reading. Most important, however, is the likelihood that the person will acquire substantial competence in the cognitive processes that are needed to engage in those reading practices. Sustained activity of reading, then, leads to

improvement in particular means of processing written language to fulfill the goals of the processor. As a result, practices of reading may be intimately tied to competencies for reading and may rightfully be construed as their origin.

There are exceptions to this model which themselves are probably rule-bound. Intensive instruction is probably one such case. That is, a particular skill such as reading celestial maps could be taught to a population, such as dwellers of a rain forest in Latin America, that had no use for it. The population then, however temporarily, possesses a competence for which it has no practice and for which it has no associated activity. Such a skill may be expected to atrophy.

It has been the attempt of this study to examine the extent to which reading in occupational settings may be described as conforming to the forecasts of the ethnographic psychology framework. Data consisting of the correlations among specific practices and specific competencies, measured via simulation tests, were substantially supportive. A total of 37 predictions from a possible 44, or 84%, was confirmed. It was predicted and confirmed, for example, that individuals who spend a relatively large amount of time searching for specific information in manuals are relatively highly skilled in the reading competency associated with that practice. Individuals who possess different uses for manuals, such as evaluation, do not acquire the same

competency; and individuals who possess this competency may not possess other competencies that are apparently required for other practices. As a consequence, it is recommended that the initial success of this model be followed up by: (1) expressing the framework in more detail, (2) developing orderly accounts for the observed exceptions, (3) testing predictions of an improved framework, and (4) delineating the implications for testing in reading, instruction in schools, and policy at the legislative level.

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Table 1

Reading Practices of Two Occupational Groups

	Groups			
	Elec. technician		Elec. engineer	
Practices	X	SD	X	SD
AKp	131	212	326	382
ASIp	42	103	52	63
AKAp	144	217	479	549
AEp	134	656	32	98
Ap	452	774	890	746
SKp	166	281	56	98
SSIp	341	889	221	483
SKAp	37	102	12	27
SEp	42	94	291	960
Sp	588	971	581	1157
MKp	351	675	239	484
MSIp	227	235	205	286
MKAp	26	36	34	57
MEp	21	56	66	239
Mp	626	728	545	860
Uses				
Kp	649	837	623	773
SIp	611	953	478	546
KAp	208	232	526	553
Ep	198	695	390	963
Pp	1666	1574	2016	1639

Note. Figures are minutes per month.

Table 2

Intercorrelation among Uses of Reading (n = 55)

		Kp	SIp	KAp	Ep
Total:	Kp	--			
	SIp	.20	--		
	KAp	.22*	.08	--	
	Ep	.03	-.01	-.08	--
Articles:	Kp	--	.12	.38*	-.03
	SIp		--	.04	.18
	KAp			--	-.08
	Ep				--
Schematics:	Kp	--	.09	.48*	.10
	SIp		--	-.03	.01
	KAp			--	.03
	Ep				--
Manuals:	Kp	--	.28*	.19	.12
	SIp		--	.44*	.36*
	KAp			--	.23*
	Ep				--

Note. Asterisk (*) indiates $p < .05$.

Table 3

Intercorrelations among Materials of Reading (n = 55)

		A	S	M
Total:	A	--		
	S	.07	--	
	M	.08	.00	--
Knowledge:	A	--	.19	.22*
	S		--	.12
	M			--
Specific information:	A	--	-.06	-.07
	S		--	.08
	M			--
Keeping abreast:	A	--	-.09	-.04
	S		--	.27*
	M			--
Evaluation:	A	--	-.02	.07
	S		--	-.05
	M			--

Note. Asterisk (*) indicates $p < .05$.

Table 4

Uses and Materials of Occupational Reading

in Electrical Science (n = 55)

Uses		Materials		
		Articles	Schematics	Manuals
Knowledge:	$\bar{X}$	220	116	300
	SD	(314)	(223)	(593)
Specific information:	$\bar{X}$	46	287	217
	SD	(87)	(729)	(257)
Keeping abreast:	$\bar{X}$	296	26	30
	SD	(434)	(78)	(46)
Evaluation:	$\bar{X}$	88	156	41
	SD	(488)	(656)	(166)

Table 5

Levels of Reading Competency for Two Occupational Groups

Competency	Group				
	Elec. Tech.		Elec. Engineer		
	X	SD	X	SD	Total possible
MSIt read before	1.9	2.1	2.5	1.9	15
AKt search time	28.6	6.3	26.6	4.8	35
AKt search acc.	2.1	1.6	3.0	1.2	5
AKt read time	16.2	5.1	14.0	4.5	25
ASIt + MSIt time	34.4	7.5	28.6	4.7	60
AKt read acc.	4.6	2.6	7.4	2.0	10
SSIt acc.	16.6	8.4	22.6	2.1	27
ASIt acc.	5.0	1.5	6.0	1.5	8
MSIt acc.	5.0	1.4	6.1	.73	7

Note. Figures are minutes for time variables; and scored points for accuracy variables.

Table 6

Reliabilities of Occupational Reading Competency Tests

	AK	SK	ASI	MSI
Cronbach &	.71	.87	.52	.37
Spearman Brown correction to about 30 items	.94	.95	.81	.70

Table 7

Intercorrelations among Occupational Reading Competencies

		AK	SSI	ASI	MSI
Total:	AK	--	.61*	.52*	.52*
(n = 55)	SSI		--	.53*	.71*
	ASI			--	.57*
	MSI				--
Elec. Tech.:	AK	--	.63*	.61*	.51*
(n = 30)	SSI		--	.57*	.72*
	ASI			--	.70*
	MSI				--
Elec. Engineers:	AK	--	-.18	.20	-.01
(n = 25)	SSI		--	.31	.03
	ASI			--	.16
	MSI				--

Note. A cross (*) indicates $p < .01$.

Table 8

Levels of Reading Competency for Four Degree Types

Degree	n	Competency							
		AKt		SSIt		ASIt		MSIt	
		X	SD	X	SD	X	SD	X	SD
High school	11	3.0	(2.4)	9.4	(9.0)	4.4	(2.0)	4.0	(1.5)
Assoc. Arts	16	5.6	(2.2)	21.6	(3.4)	5.6	(1.0)	5.7	(.9)
Bachelors	11	7.8	(1.4)	22.4	(2.0)	5.6	(1.9)	6.0	(.6)
Masters	8	5.9	(1.8)	23.0	(2.5)	5.9	(1.1)	6.1	(.8)

Note. Figures are accuracy scores.

Intercorrelations for Occupational Reading Competencies and the Nelson-Denny Test for Two Occupational Groups

Groups	Competencies				NDPR	
	AK	SK	ASI	MSI	X	SD
Total (n = 55)	.64+	.48+	.52+	.46+	49.9	33.9
Elec. Tech. (n = 30)	.54+	.41*	.39*	.31*	32.0	27.1
Elec. Engineers (n = 25)	.41*	.12	.52+	.25	71.5	28.4

Note. The cross (+) designates $p < .01$; and the asterisk (*) indicates $p < .05$. NDPR is Nelson-Denny percentile rank for end of sophomore college normal.

Table 10

Simple Isomorphic Model of Practices and Competencies:

Predictions and Observations

Practices	Competencies (n = 55)			
	AKt	SSIt	ASIt	MSIt
AKp + AKAp	±	o	o	o
ASIp	+	+	±	o
AEp	+	+	+	o
SKp	+	+	+	+
SSIp	+	-	+	+
SKAp	+	+	+	+
SEp	+	+	+	+
MKp	+	+	+	+
MSIp	+	+	+	±
MKAp	+	+	+	+
MEp	o	+	+	+

37/44 = 84%

Note. + designates prediction confirmed by observation.

± designates important confirmations.

o designates observed correlation not predicted.

- designates predicted correlation not observed.

Table 11

Correlations among Practices and Competencies for Simple Isomorphic Model

Practices	Competencies			
	AKt	SSIt	ASIt	MSIt
AKp + AKAp	.22*	.36+	.30+	.34+
ASIp	-.08	-.19	-.23*	-.36+
AEp	-.06	-.19	-.03	-.28*
SKp	-.09	.05	.00	.07
SSIp	-.14	.19	.01	.13
SKAp	-.15	-.02	-.03	.01
SEp	.02	.13	.11	.21
MKp	-.01	.11	.03	.04
MSIp	.01	.13	.02	.23*
MKAp	-.04	.05	.06	.15
MEp	.22*	.05	-.09	.15

Appendix 1
Articles for Knowledge Test

Appendix 1A

Articles for Knowledge Test

Directions

1. Each item consists of one article and four questions. Only one of the questions is answered in the article.

2. Read and remember the questions.

3. Find the section in the article that provides the fullest answer to one of the questions. Try skimming (scanning) the article first.

4. When you have found the section, tell me so I can record the time. If after 7 minutes you have not located the section, I will show you.

5. Read the section until you understand it well enough to write the answer in a few sentences. Tell me when you have finished reading and I will record the time. After 5 minutes, I will ask you to answer the question whether you have finished reading or not.

6. Answer the question as fully and accurately as possible without referring to the article.

7. The first item will be a practice item.

Appendix 1B

Test Item 1 from AKT

1. What are the proposed standards for microfloppy disk drives?

2. What problems with 5 1/4" floppy disks have caused consumers to turn to the microfloppy disk as the preferred data storage medium?

3. What differences in format between U.S. and Japanese manufacturers have slowed the advance of the microfloppy disk technology?

4. What are the problems that limit the manufacturing capacity of sub 5 1/4" floppy disks?

Sample Answer

As of Feb. 84:
1) MIC/SONY Compromise 80 track, 3 1/2 hard shell 625Oe coercivity and about 60u in coating
2) Dysan/Tabor 3 1/4 inch soft shell
3) 3 inch hard shell CFO from Maxell/Hitachi/ Matsushita companies. (Answer was scored 2--perfect score.)

Necessary Factors as Confirmed by Consultants

1. 3 1/2 hard covered disk with metal hub
2. 3 1/4 inch soft covered
3. 3 inch hard shelled

Loacated in the section "Setting standards for microfloppies" on page 49 of EDN, November 10, 1983.

Lack of standards, units and vendors clouds microfloppy-disk-drive horizon

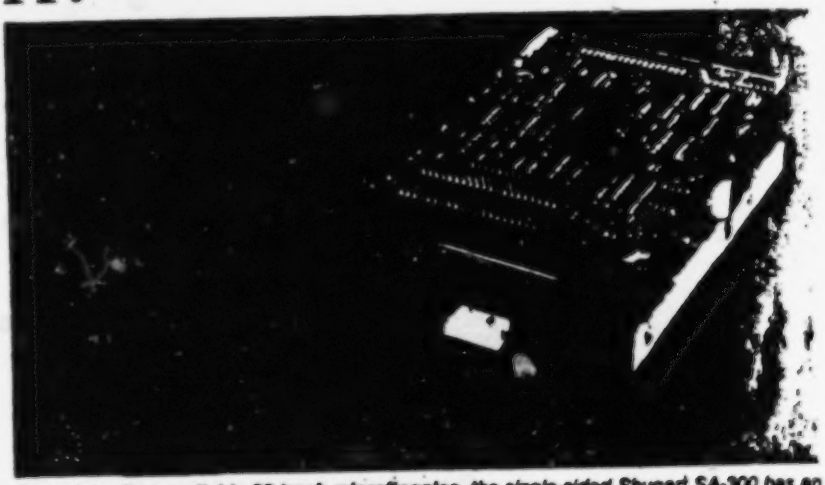
Don Powers, *Associate Editor*

Lack of standardization in recording format, few hardware manufacturers and a reluctance on the part of media suppliers in developing products are the problems that face users considering a sub-5¼-in. floppy-disk drive for their next design.

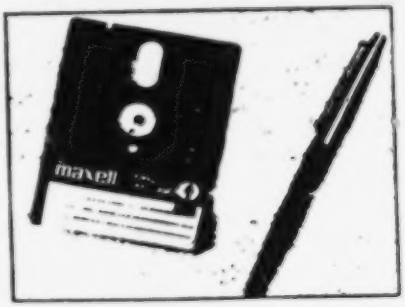
In fact, these drawbacks in 3-, 3½-, and 3¼-in. microfloppy development are turning what was intended to be a major applications offensive against 5¼-in. disks into a minor skirmish. Indeed, more than 80% of the recently introduced briefcase-size computers that employ drives are using 5¼-in. versions. It's surprising if you consider that these portable units have the most to gain from a reduction in component size. It's not so surprising, however, upon further scrutiny.

The wide range of choices (reminiscent of the Betamax vs VHS format scramble in videotape developments a few years ago) is actually helping stunt the growth of microfloppies. Many media manufacturers are not completely enamored with the technology because proposed microfloppy drives are either late in materializing or just beginning to gain OEM acceptance. As an example, consider BASF, a large, international media manufacturer: Although the firm has separate divisions licensed to make 3- and 3½-in. disks, it produces neither.

What's more, some microfloppy-drive manufacturers are themselves refusing to help the cause. For example, Canon USA and IBM have both stopped producing sub-5¼-in. drives, and Hitachi, while still making a 3-in. version, has chosen not to offer it for sale in the US directly (the marketing is being done by Amdex).



One of the first available 80-track microfloppies, the single-sided Shugart SA-300 has an MFM formatted capacity of over 400k bytes.



With separate write protects for each side, you can flip over this 3-in. Maxell disk to use its full 500k bytes of storage capacity (unformatted).

But if this reticence on the part of microfloppy-media and disk-drive manufacturers doesn't dissuade you from forging ahead into regions unknown, then proceed—but be forewarned. Available 3- to 3½-in. products do offer designers advantages (to varying degrees) over their 5¼-in. relatives. These include smaller size, weight and power requirements; greater data protection and portability; and data storage comparable to 48- and 96-track 5¼-in. disks. (1M-byte drives are also currently available.)

While any microfloppy-drive manufacturer can promise you all these features, you can determine what best suits your needs by first looking at the media and then selecting the drive that best meets your price/performance goals (see nearby table of microfloppy-disk features).

The three sizes of microfloppy disks currently vying for portable μC market share all offer more than just the advantages listed above for designers. (Sub-3-in. units aren't counted because storage capacity is limited to approximately 16k bytes; for a historical perspective, see box, "Setting standards for microfloppies.") Indeed, the smaller size reduces the medium's sensitivity to environmental factors. This reduction eventually leads to storage densities 10 times greater than 5¼-in. versions.

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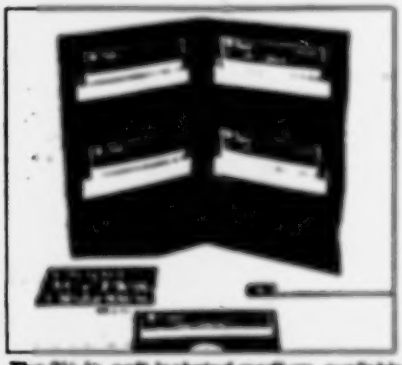

The 3½-in. soft-jacketed medium, available from Dysan Corp and Brown Disc Manufacturing, provides 500K bytes of unformatted storage on a single-sided disk and 1M byte on a dual-sided disk.

tation arises from the need to position the drive head repeatedly over the same area on the Mylar medium, which itself is subject to positional shift. As physical distortion due to humidity and temperature is directly proportional to medium size, the smaller microfloppy disks are automatically less susceptible than their 5¼-in. counterparts.

Furthermore, because microfloppy disks have a metal (3½- and 8½-in. disks) or plastic (3-in.) hub, an order of magnitude improvement in disk-seating accuracy is provided. Both of these improvements, combined in some cases with higher coercivities and lower oxide densities, raise the upper limit on storage density considerably compared with larger floppy disks.

One common concern among both microfloppy-media and -drive manufacturers that's beginning to rage is that of medium portability and protection. Many people, including members of the Microfloppy Industry Committee (MIC), indicate the need for "shirt-pocket" portability for these smaller disks, and considering size alone, all qualify. The soft-medium jacket material on 8½-in. versions is the same as that used with 5¼-in. disks. All current 8- and 3½-in. disks have cartridge-like hard-plastic cases with automatic shutters that open when the disk is inserted into the drive.

In the design of its 3½-in. drive, Tabor Corp opted for a flexible jacket format, according to president Michael F Hanley, because the proven technology of this format lends itself to currently available manufacturing techniques, and because the medium has the most effective wiping action of the microfloppy disks—cleaning the medium as it rotates. A hard shell, he notes, adds bulk and weight and raises questions concerning reliability because it has more moving parts "and, as a new product, remains to be proven in the field."

But Verbatim Corp, which manufactures a 3½-in. microfloppy, doesn't quite agree, according to president Mal Northrup. In response to soft-jacket proponents, Northrup agrees that this medium has proven itself but argues that it shouldn't stop something better from being made. Both he and Scott A DeHart, Hewlett-Packard's microfloppy product manager, counter that handling damage is the greatest cause of floppy failure; such damage can be reduced by a hard shell combined with an automatic shutter and center hub as used on 3½-in. microfloppy disks.

Those favoring the 3-in.-medium format agree, adding that its shutter is more difficult to open manually than the one on the 3½-in. disk. In addition, the 3-in. case has two write-protect tabs, one for each side, to prevent accidental loss of data. (Other media sizes have one write-protect tab.) These 3-in.-medium proponents naturally equate both of these features with improved reliability.

Hewlett-Packard, however, justifies its choice of medium with much harder facts. The company recently shipped its 25,000th 3½-in. Sony 70-track drive, and in the first nine months of an audit test run, there have been no soft errors (five drives are selected daily and tested for 24 hrs). According to HP's DeHart, this projects to three orders of magnitude better than originally

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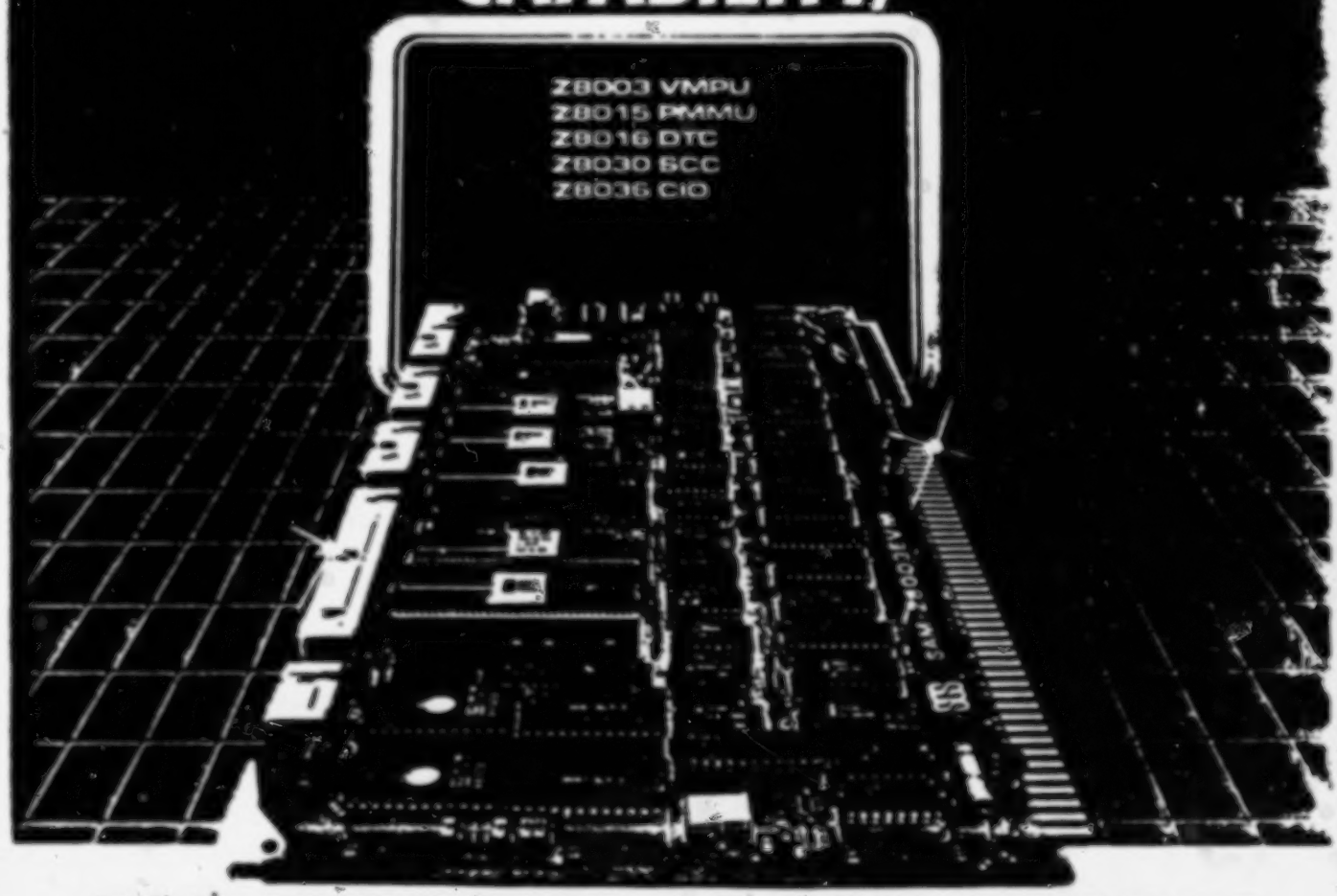

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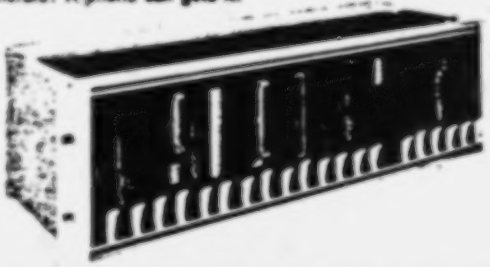

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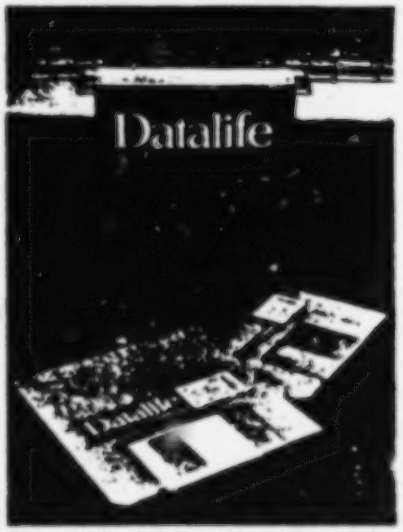

Three 3½-in. disk formats, each employing a hard case and automatic shutter, are available from Sony and Verbatim: 70- and 80-track single-sided cartridges and 80-track double-sided cartridges (Verbatim only supplies 80-track versions). Maximum unformatted storage on a dual-sided disk is 1M byte.

expected and specified—a soft error rate of 10^{-12}. "From warranty data," he states, "we are seeing one quarter of the failures per 1000 units that we experience with our 5¼-in. drives." Users testing the other medium sizes have experienced similar results, but under more limited testing.

Beyond size itself, price might also be a qualifying factor in medium selection. While Tabor's Hanley says that the use of a hard-plastic case could prove to be more expensive to produce than soft-jacket products, Verbatim's Northrup feels that in high-volume, fully automated production, the labor cost differences will disappear, leaving only small differences in raw-material costs—a small part of total manufacturing costs. Northrup believes that either the hard- or soft-cased microfloppy disk will probably have an ultimate cost very close to that of current 5¼-in. disks of equivalent capacity. At the present time, expect to pay between $6 to $7 for each medium, except where the supply is tight.

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TECHNOLOGY

Notwithstanding all of these concerns that prospective users of microfloppy-disk media and drives might face, an overview of available products should prove useful.

In general, within the three size formats, either frequency-modulation (FM) or modified-frequency-modulation (MFM) recording techniques are being used. FM alternately stores a data bit and a clock pulse on the disk as different frequencies. A pulse is therefore a shift in the recording frequency. If data is a ONE, a pulse is written half the distance between two clock pulses; in the case of ZERO, no pulse is written. With MFM, a clock pulse is written *only* if the next and previously written data bits are *both* ZEROs. It is written at the start of the second ZERO's bit space (at a third frequency), eliminating the disk area required by clock pulses—and doubling the available data-storage area. The flux changes per inch are the same; it is a different storage technique rather than an increase in density that provides the added data storage.

The 3-in. disk, also referred to as the compact floppy disk (CFD), is the smallest practical medium—so far. (Sankyo Seiki makes 2½-in. disks, but dual-sided storage capacity is only 16k bytes.) The current 3-in., 100-tpi, 40-track, double-sided hard-shell disk (see table) is the first step in a chain of CFDs that promise increased data storage capacity.

As with other microfloppy drives, the units that use the 3-in. medium are available with single- or double-density recording/retrieval capabilities. Single-density versions typically employ the FM data-storage technique, while double-density drives use MFM.

In 1984 data density should double with the appearance of a 200-tpi, 80-track CFD, according to Dave Berry, OEM sales and products manager for media suppli-

109

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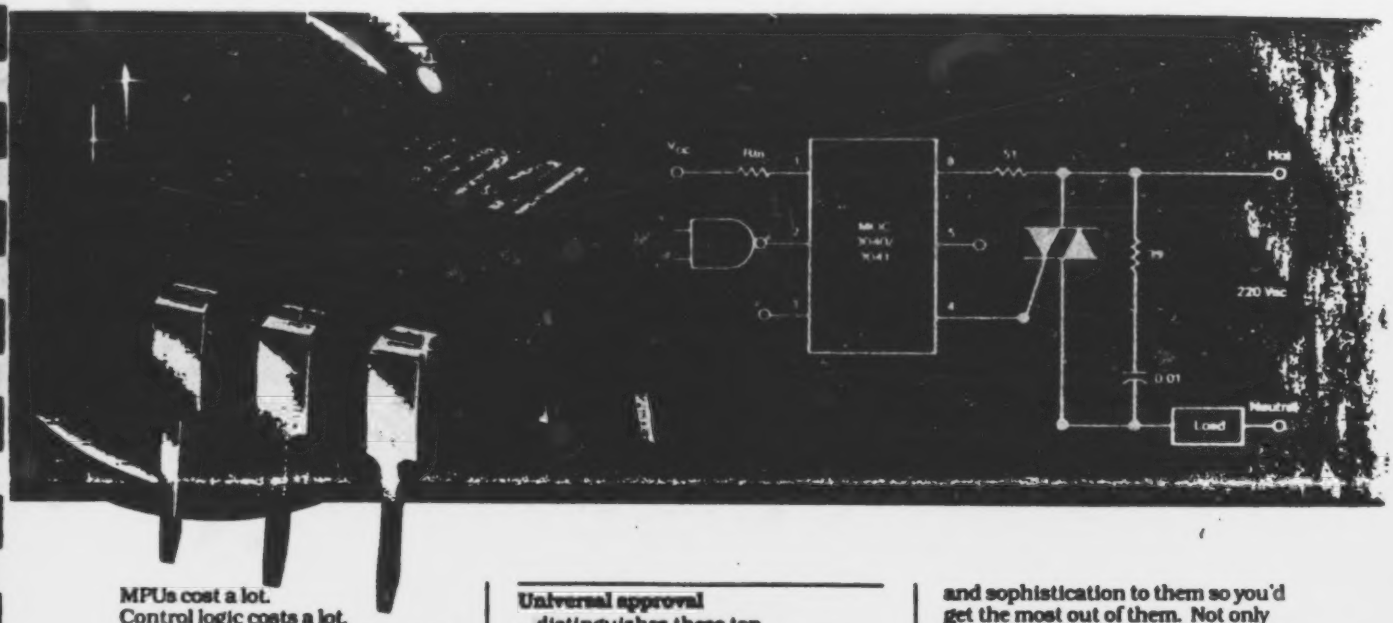

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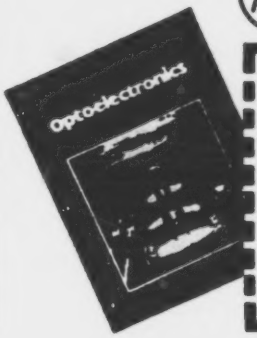

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TECHNOLOGY UPDATE

er Maxell Corp. He predicts a further increase in 1985 from 500k bytes per side to 800k bytes through improved bit density. A new substrate material that is less disposed toward humidity and temperature distortion will account for this improvement.

Maxell currently supplies a double-sided CFD, the CF-2. When used with a single-sided drive, the CFD is flipped over to use the other side, according to Berry. The automatic shutter operation isn't affected.

To make use of these disks, you can purchase 3-in. drives from Amdek—the single-head Amdisk III—and from Sankyo Seiki, which makes a dual-head (FDU-300DA) as well as a single-head model (FDU-300SA). Amdek offers evaluation samples for $200; a packaged dual-drive unit with power supply and four diskettes is available for $499. Sankyo Seiki is sampling both of its drives at $350.

For compatibility with 5¼-in. drives, these units offer identical recording formats and plug-compatible interfaces (Sankyo units; the Amdek unit interfaces via a 37-pin D-shell connector). They operate at the same voltage levels (all units require less current; be sure to compare this specification since differences exist). The units rotate at 300 rpm, which translates into a data-transfer rate of 250k bps. In addition, each offers an MFM inner track density of 8946 bpi, which suits medium specifications. The units weigh approximately 1.5 lbs each.

Moving up in medium size, Dysan Corp and Brown Disk Manufacturing Inc produce soft vinyl-jacketed 3¼-in. floppy disks. These disks closely resemble the 5¼-in. floppy and are available in both single- and double-sided soft-sided certified versions. With a coating thickness of 50 μin. and a coercivity of 600 (Dysan) or 640 (Brown) Oe (oersteds), the manufacturers are designing the 140-tpi, 80-track microfloppy disks to have an unformatted data density in the 10,000-bpi range. A 0.95-in.-diameter metal hub provides posi-

MICROFLOPPY DISK FEATURES

SIZE (IN.)	3	3 1/4	3 1/2	3 1/2
NO TRACKS PER SIDE	40	80	70	80
DENSITY (TPI)	100	140	135	135
NO OF SIDES[1]	2	1/2	1	1/2
TOTAL STORAGE UNFORMATTED (M BYTES)[2]	0.5	0.5/1	0.4375	0.5/1
COATING THICKNESS (μIN.)	39	50	100	60
COERCIVITY (OERSTEDS)	635	600/640	580	625
COVER	HARD	SOFT	HARD	HARD
SHUTTER	YES	NO	YES	YES
HUB	PLASTIC	METAL	METAL	METAL
WRITE PROTECT (PHYSICAL)	YES	YES	YES	YES
WIDTH (IN.)	3.15	3.27	3.54	3.54
LENGTH (IN.)	3.94	3.43	3.7	3.7
THICKNESS (IN.)	0.20	0.06	0.13	0.13

NOTES:

1. 1/2 INDICATES BOTH SINGLE- AND DOUBLE-SIDED DISKS AVAILABLE.
2. STORAGE TOTALS ARE FOR DOUBLE-DENSITY MODIFIED FREQUENCY-MODULATION (MFM) STORAGE.

tioning accuracy to within 200 μin. The 3¼-in. size was devised, say the suppliers, for cost effectiveness as well as convenience; Dysan punches three 3¼-in. disks from an 8-in. coated blank with only an additional punching step.

Tabor Corp is the only company currently manufacturing drives for 3¼-in. disks. A one-piece-casting backbone chassis, mechanically simple receiver mechanism and direct-drive spindle motor that eliminates belts result in fewer moving parts than other microfloppies, thus

Setting standards for microfloppies

To understand the current state of the microfloppy standards debate—permitting you to be better informed before making a judgement on the proper medium for your needs—you should know the microfloppy two-year-plus history. Sony was the first to enter the microfloppy market with its 3½-in., 70-track, 600-rpm single-sided disk drive. (70 tracks were selected because that was twice the number on the then-popular 35-track, 5¼-in. drive. 600 rpm provides the same transfer rate as a double-density 8-in. drive.) Originally built with a manual shutter, it now uses an automatic one. In terms of numbers sold, this is by far the most popular unit. For example, Hewlett-Packard shipped its 25,000th Sony-built 70-track unit in June, making the company the largest OEM supplier of microfloppy drives.

Two additional microfloppies were introduced in 1981. A group consisting of Hitachi, Maxell and Matsushita introduced a 3-in., hard-shelled compact floppy disk (CFD). One justification for this size, at least in Japan, is postal costs. The 3-in. disk fits into a standard business envelope requiring less postage than one containing a 3½-in. disk. That same year, Canon USA Inc announced a 3.8-in. disk and drive, since withdrawn.

In an attempt to alleviate the growing confusion and potentially greater costs of drive proliferation, a group of disk and drive manufacturers formed what is now the Microfloppy Industry Committee (MIC) in June of 1982. This group, which comprises almost two dozen members, attempted to develop and promote a microfloppy standard acceptable to the entire industry.

Customer research by MIC members identified three criteria which were vital to product acceptance: size (the medium had to fit in a shirt pocket), protection (required to carry the medium safely in a pocket or purse) and compatibility (with standard minifloppy media to protect current and future software investments).

The MIC settled on a 3½-in. disk with a hard case and metal hub similar to Sony's. There were four major areas of difference between the Sony disk and drive and the MIC proposal: shutter type, 5¼-in. compatibility, medium coercivity and magnetic-coating thickness. For greater medium protection, an automatic shutter replaced the original manual one.

To make the microfloppy disk and drive drop-in compatible with existing standard 5¼-in. drives, the number of tracks per side (both single- and double-sided disks were allowed) was increased from 70 to 80 (along with disk data format changes), drive interconnects were changed for pin-for-pin compatibility, and the drive rotation speed was dropped from 600 to 300 rpm to provide the standard 250k-bps transfer rate. Provision was also made for 40-track disks for low-end compatibility, but manufacturers have shown little interest in pursuing this format.

The coercivity of the media in the MIC proposal was 650 Oe (an oersted is a centimeter-gram-second electromagnetic unit of magnetic intensity) as opposed to Sony's 580 Oe; an ozide layer 40 to 50 μin. thick was suggested instead of Sony's 100 μin. Both of these changes were proposed to make higher density recording more reliable.

By the time the MIC met with the ANSI X3B8 committee in September 1982, Dysan and Tabor had introduced a 3¼-in., soft-covered entry. Four formats were thus competing for approval: the MIC 80-track 3½-in. unit, the original Sony 70-track 3½-in. microfloppy, the 3¼-in. device from Dysan and Tabor, and the 3-in. CFD proposal.

The number of contenders shrank to three in January of 1983, when the MIC and Sony agreed on 80 tracks per side on a disk, full 5¼-in. compatibility, a coercivity of 625 Oe and an oxide thickness of approximately 60 μin. Sony continues to manufacture its 70-track product with automatic shutter and is producing a second generation of 80-track drives compatible with MIC proposals. In addition, both Sony and Tandon are producing 80-track, 600-rpm drives with the original (70-track) Sony OA-D30V interface and disk data format.

This February, IBM presented its 4-in. disk and drive, returning the number of proposals to four. However, it withdrew this entry in September, according to Hayes Price, IBM OEM marketing and planning manager. The number of entries again stands at three. As ANSI continues to work on providing one or more standards, most observers and participants agree on one point; the marketplace will provide the de facto standards, with officially sanctioned standards following.

increasing reliability.

Two drives currently available from Tabor include the single-sided TC-500, which lists for $225, and the newly announced dual-sided TC-1000, listing for $295. The drives use either FM or MFM encoding and have inside-track MFM recording densities of 9250 bpi. Using MFM, the drives have formatted storage capacities of 328k and 656k bytes, respectively. Both are compatible with 5¼-in. drives in terms of signal interface, power (less current required) and data-transfer rate (250k bps based on a 300-rpm rotational speed). Weighing 1.6 lbs, the drives measure 1⅛×4×5½ in. They operate from 5 to 46°C with a relative humidity of 20 to 80%. As a point of interest, Seagate Technology has already announced that it will build the drive under license, according to Tabor's VP of marketing George Rea.

Among the three different microfloppy-disk types, the 3½-in. medium offers the most variety. While the exteriors are physically similar (all hard cased with automatic shutters), three formats exist: 70-track single-sided, 80-track single-sided and 80-track double-sided. Sony Corp will continue to support and deliver both 70-track media and drives, numerically the most popular to date. In agreement with MIC, Sony is supplying single- and double-sided, 80-track microfloppy disks and drives. Verbatim Corp is also supplying 80-track media.

Either because of initial backing by Sony and HP, or possibly due to higher density capability, there are more 3½-in. drive types and manufacturers than with any other size. Types are classified according to sides, the number of tracks per side and revolutions per minute. All have recording densities of 135 tpi.

There is only one drive designed for 70-track recording—the single-sided OA-D31V manufactured by Sony and used by Sony, Hewlett-Packard and others. The first microfloppy drive type available, it is the most popular in terms of units sold. The drive supports diskettes with automatic shutters, and its direct-drive brushless motor rotates at 600 rpm with a 500k-bps transfer rate using MFM, the only format supported. Interface is via a 26-pin ribbon connector which is referred to as the OA-D30V interface after the original Sony model.

Meanwhile, Tandon and Sony are supporting the four announced 80-track drive configurations and intend to manufacture all types. These configurations include single- and double-sided MIC-type drives (300-rpm drives supporting either FM or MFM format with a 5¼-in. compatible interface) and single- and double-sided Sony speed/interface-type drives (600-rpm drives supporting only the MFM format with a OA-D30V-type interface). Disk format and software are not compatible among the two types.

Prices for single-sided 80-track drives are approximately $200 (±10%) in large OEM quantities, with no price difference between 300- and 600-rpm versions. In addition, Shugart and Mitsubishi Electronics America offer single-sided MIC-compatible drives. No prices have been released for either the newly announced Sony or Tandon double-sided drives. EDN

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For more information...

For more information on the microfloppy disks and drives described in this article, contact the following manufacturers directly or circle the appropriate numbers on the Information Retrieval Service card.

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Appendix 1C

Test Item 2 from AKT

1. What are the limitations on SWOP amp switching speed?

2. How do switchable input OP amps facilitate system calibration?

3. How do switchable OP amps improve system reliability?

4. How has noise gain been reduced to improve signal to noise ratio?

Sample Answer

The "SWOP" amp has two independent inputs that are selectable digitally. In order to use this for testing a system, a reference signal or known waveform can be placed on one of the inputs, and the "normal" signal is fed into the other input. By switching in the known reference, the resulting output can be monitored for gain, or noise, in whatever function is important to the designer. The use of the common circuitry makes this a potentially better test because if separate OP amps are used, additional unknowns will exist in the circuit. (Answer was scored 2--perfect score.)

Necessary Factors as Confirmed by Consultants

Software switchable inputs allow switching in reference voltages for 1) autozeroing, 2) gain calibration, 3) waveform verification.

Located in the section "Software performs autozeroing tasks," on pp. 259-260 of EDN, January 12, 1984.

Multiplexed inputs on op amp simplify a variety of circuits

Using two multiplexed inputs, a switchable-input op amp allows you to implement functions ranging from selectable-input amplifiers to autocalibration circuits—all with a low parts count.

Tom Anderson, *Burr-Brown Corp*

Designing a switching function into a precision analog circuit without compromising accuracy, reliability or cost can be difficult. But integrating the switching circuit into an op amp avoids the tradeoffs imposed by using alternatives such as relays, FET switches and multiplexers. The switchable-input op (SWOP) amp can thus improve and simplify circuits that involve multiple inputs or transfer functions.

The nature of the SWOP amp's internal switching elements (see box, "Inside the SWOP amp") permits a clean switching function. In contrast, FET switches and multiplexers exhibit On resistance and Off leakage currents, which require detailed attention to impedance levels, particularly at high operating temperatures. Relays, on the other hand, feature higher accuracy, but also higher cost and limited lifetimes compared with semiconductors.

Before examining several application examples, consider some of the SWOP amp's characteristics. Multiplexing occurs via the device's two matched input stages and channel-select circuitry (**Fig 1**). A digital channel-select signal enables one input by turning off the unselected input stage; only the On channel can then send signals to the following stages.

Although the applications detailed in this article employ ground-referenced TTL signals, the channel-select circuitry is compatible with several logic families. You can reference logic levels to ground, $-V_{CC}$ or virtually any other point by connecting the SWOP amp's threshold-control pin to the appropriate voltage.

A low-power device, the SWOP amp typically draws 350 μA of supply current. You can employ either a single or split power supply ranging from 5 to 36V. Combining wide supply range and low power with precision performance suits the SWOP amp for use in portable or remote battery-powered systems. Applications such as isolated systems and robotics functions can also benefit from the device's analog signal-conditioning and -steering capabilities.

Put selectable inputs to work

Perhaps the most obvious use for the SWOP amp is in systems that require selectable inputs. The simplest circuit of these types is the selectable-input buffer shown in **Fig 2**. It uses both channels as high-input-

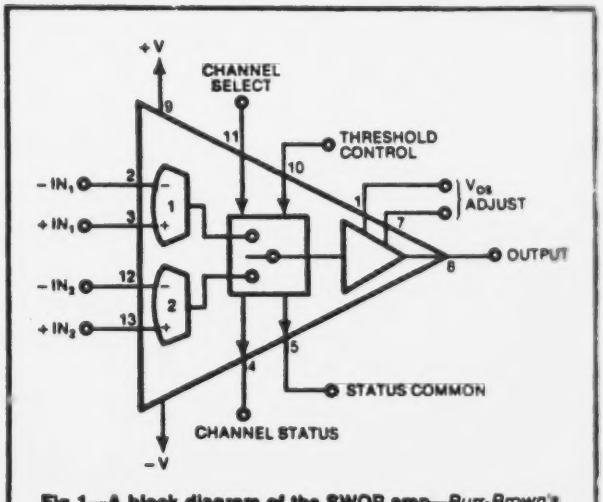

Fig 1—A block diagram of the SWOP amp—*Burr-Brown's OPA201—shows the device's two input stages, switching function and output amplifier.*

SWOP amp's select circuitry is compatible with most logic

impedance voltage followers. In this circuit, the SWOP amp needs no external parts.

Applications for the circuit include remote or computer-controlled systems that must select and buffer fairly high-level signals. These signals could originate from transducers such as thermocouples or strain gauges, for example, or represent the voltage and current associated with a motor.

For voltage signals, the circuit functions as a near-ideal switch with high input impedance and low output impedance. High open-loop gain and CMRR guarantee excellent accuracy and linearity.

Similarly, the SWOP amp provides a minimum-parts-count approach to amplifying low-level signals. You can configure each channel to provide noninverting or inverting gain by following standard op-amp design considerations. If you want the same noninverting gain on both channels, for instance, the SWOP-amp inputs can share one set of feedback resistors, with the inverting inputs on each channel tied together (Fig 3a).

For different gains on each channel, use independent

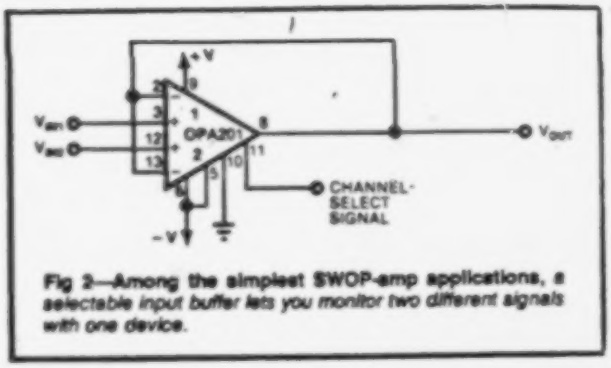

Fig 2—Among the simplest SWOP-amp applications, a selectable input buffer lets you monitor two different signals with one device.

Inside the SWOP amp

A simplified schematic of Burr-Brown's OPA201 SWOP amp appears in **Fig A.** The circuit has four sections: input stage 1, input stage 2, active load and output amplifier, and channel-select circuit.

The two precision differential input stages are identical, and their laser-trimmed offset and drift characteristics result in tight matching (see nearby table). Because these input stages share a balanced, high-precision active load and external offset-adjust pins, offset adjustments affect both channels. (**Fig B** shows how you can use an inexpensive CMOS IC to alternately connect one of two independent offset-adjust pots.) The input stages also share a gain stage and an output amplifier, making the characteristics of the two channels nearly identical.

The channel-select circuitry allows only one input stage at a time to be active; the selected input stage controls the output amplifier. The channel-select circuitry keeps the unselected input stage off by deactivating that stage's bias circuitry (patent pending).

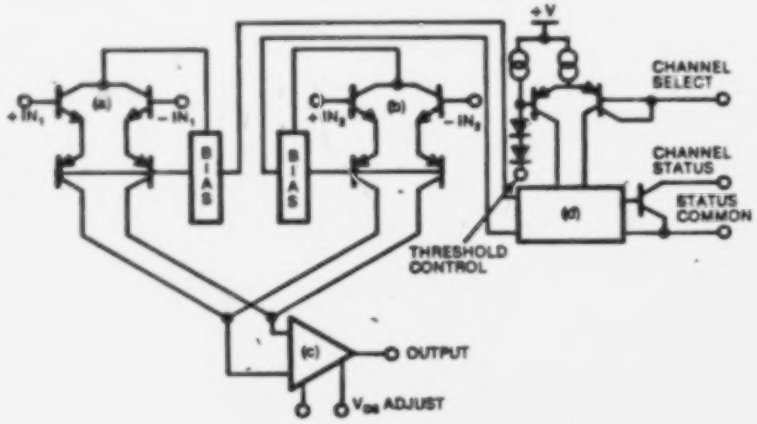

Fig A—A simplified schematic of the SWOP amp *indicates the device's four parts: input stage 1 (a), input stage 2 (b), an active load and output amplifier (c), and a channel-select circuit (d).*

SWOP AMP KEY SPECIFICATIONS

At T = 25°C, +V = +15V dc, −V = −15V dc

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
V_{OS}			35	100	μV
V_{OS} DRIFT	−25 to +85°C		0.5	1.0	μV/°C
dV_{OS} (MATCH)	$(V_{OS1} - V_{OS2})$		25	50	μV
dV_{OS} DRIFT	−25 to +85°C			1.0	μV/°C
I_B				25	nA
I_{OS}				1	nA
SLEW RATE			0.2		V/μSEC
PSRR		100			dB
CMRR		95			dB
A_{OL}	R_L = 10k, V_O = ±10V	120	130		dB
CROSSTALK	V_{IN} OFF = ±12V	120	130		dB

feedback networks or the three resistors shown in Fig 3b. When each channel has independent feedback, treat the Off channel's feedback as a component of the load impedance for design purposes.

Dual-input inverting amplifiers require independent feedback networks, yet they prove worthwhile in applications such as circuits that monitor voltages higher than the available supply voltages. Because the SWOP amp's common-mode voltage is always near zero, the input voltages can exceed the supply voltages. Although this capability isn't unique to the SWOP amp, it does allow a 2-input system with low supply levels to monitor high-voltage signals by using gains less than unity.

Fig 3c illustrates circuits with gains of −10 and −0.1. Note that V_{IN} produces ±10V outputs for ±100V inputs. The amplifier's low input bias current (25 nA max) and input offset current (1 nA max) permit a wide range of impedances high enough to limit the maximum output-current requirement without introducing excessive errors.

Software performs autozeroing tasks

The selectable-input technique also provides a straightforward method for software to command the autozero of system offset errors. One SWOP-amp channel processes signals, and the other has its input grounded. (Both channels thus have the same gain.)

Fig 4 shows a circuit that can software-autozero the offset error of a 3656 isolation amplifier. The 3656 provides both signal isolation and isolated power for the SWOP amp. When choosing the component values for this circuit, set the SWOP amp's gain to limit the 3656 input voltage to ±5V. The output section of the 3656 permits a single 5V supply to provide power for the SWOP amp and a channel-select controller.

As an additional feature, an open circuit on the channel-select pin selects channel 1. This characteristic allows an open-collector transistor—or phototransistor—to control the channel-select input without a pull-up resistor. When you aren't using a pull-up resistor, limit the input's leakage to 20 μA to ensure that channel 1 is indeed selected, because that's the value required to pull the channel-select pin Low.

The channel-status open-collector output is referenced to the status common pin. When used with a pull-up resistor, the status output indicates the logical inverse of the channel-select signal. This feature comes in handy for such tasks as switching in dual external offset-adjust pots, indicating polarity in absolute-value circuits and level shifting the logic signal. When not used, leave the channel-status pin open and tie status common to −V.

For more information on the OPA201 SWOP amp, **Circle No 749.**

The unselected stage thus receives negligible input bias current, and the Off channel cannot send signals to the output amplifier. This channel rejects signals applied to it as well, as shown by the SWOP amp's −120-dB crosstalk spec.

The Off channel, therefore, can be modeled as an open circuit in most designs. You can expect input currents typically less than 15 pA for input voltages inside the device's common-mode range. Although the SWOP amp's data sheet specifies crosstalk for voltages equal to the common-mode extremes, the same Off-channel rejection characteristics usually remain valid for all input voltages between −V and (+V−1V).

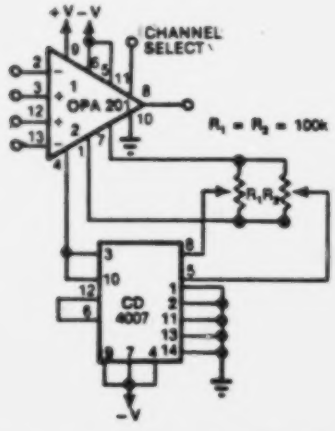

Fig 8—Dual independent offset adjustments can be switched in using a CD 4007 IC. R_1 adjusts only channel 1; R_2 adjusts only channel 2.

Easy-to-use circuitry

The SWOP amp's channel-select circuitry is versatile yet simple to use. The threshold control (pin 10) sets the trip point for changing channels. Channel 1 turns on when the channel-select voltage increases to more than two diode drops above the threshold-control voltage; channel 2 turns on when the channel-select voltage decreases to less than two diode drops above the threshold-control voltage. Thus, the channel-select voltages are compatible with ground-referenced TTL levels when you ground the threshold-control pin.

When using low supply voltages, however, you can achieve better results by connecting the threshold-control pin to the −V pin. For example, this connection

Minimum number of parts needed to amplify low-level signals

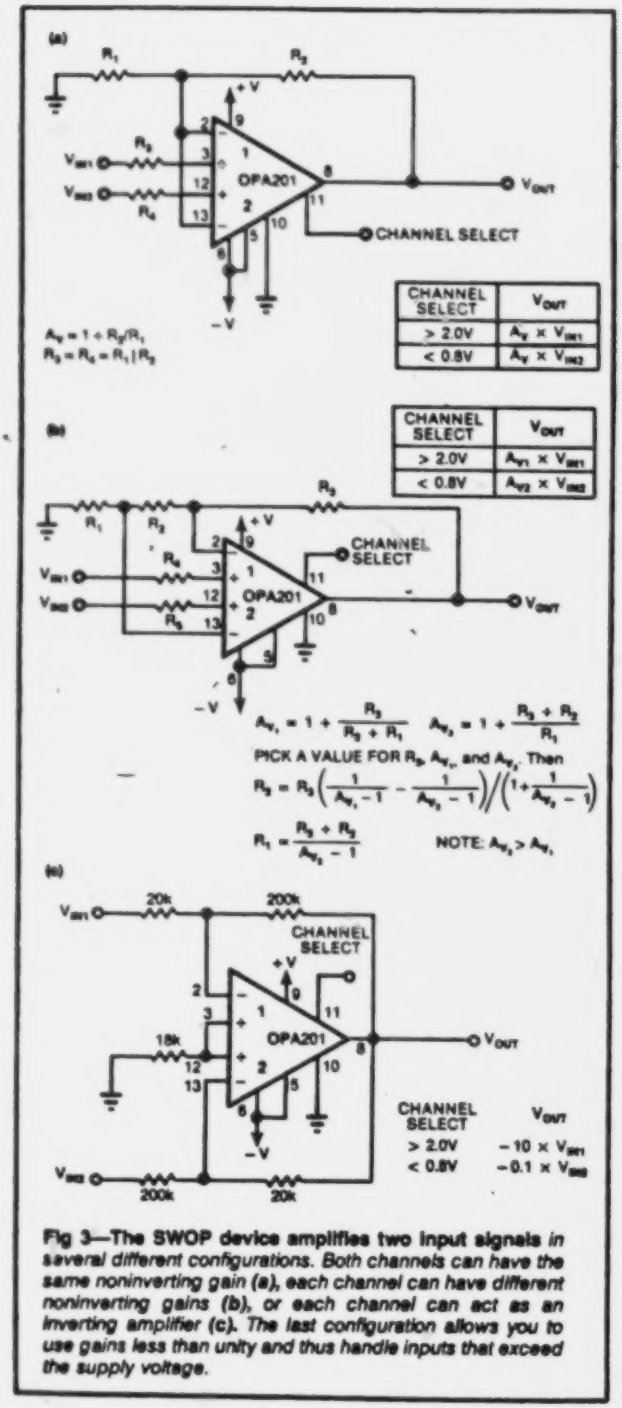

Fig 3—The SWOP device amplifies two input signals *in several different configurations. Both channels can have the same noninverting gain (a), each channel can have different noninverting gains (b), or each channel can act as an inverting amplifier (c). The last configuration allows you to use gains less than unity and thus handle inputs that exceed the supply voltage.*

can furnish a gain of 2 to raise the output swing to ±10V.

A 4N25 optocoupler isolates the channel select (or zero command) signal. When the zero-input channel is selected,

$$V_{OUT} = V_{ISO} + (A_V \times V_{OS2}),$$

where V_{ISO} equals the isolation amplifier's V_{OS}. A_V is the SWOP amp's voltage gain, which equals $1 + R_2/R_1$, and V_{OS2} is the SWOP amp's V_{OS} for channel 2. When the signal channel is selected,

$$V_{OUT} = V_{ISO} + (A_V \times V_{OS1}), + (A_V \times V_{IN})$$

where V_{OS1} is the SWOP amp's V_{OS} for channel 1.

Subtracting the zero-input V_{OUT} from the signal V_{OUT} with software leaves a corrected output voltage:

$$V_{OUT} = (A_V \times V_{IN}) + A_V \times (V_{OS1} - V_{OS2}) = A_V \times (V_{IN} + dV_{OS}),$$

where dV_{OS} is V_{OS} between the two SWOP-amp channels, which equals 50 μV max. Note that the 3656's offset (typically 5 mV+200 μV/°C) has been removed from V_{OUT}; the only offset error represents the mismatch between the two SWOP-amp input stages (50 μV+1 μV/°C max).

Using a signal instead of ground on channel 2's input opens the door to a wide range of system-calibration and signal-check applications. You can use the circuit to select a reference for gain calibration or switch in a waveform at a system's front end to verify that the system functions correctly.

To implement a single-chip chopper-modulator circuit for amplitude modulation, use a system clock to drive the SWOP amp's channel-select pin and switch continuously between a signal input on one channel and ground on the other. Variations on this idea include synchronous-demodulation and quadrature-detection systems that have low parts count and high performance.

Select a transfer function

Instead of using the SWOP amp to deal with dual inputs, you can start with a selectable-input amplifier that has different gains for each channel and connect the inputs together (Fig 5). You now have a selectable-gain amplifier—extremely useful for extending a system's dynamic range and resolution. In this configuration, the channel-select pin serves as a gain-select input, which can be operated by remote control.

Selectable-transfer functions extend beyond selectable gain, with selectable bandwidth among the most useful. For example, you can switch in smoothing (lowpass) or ac-coupling (highpass) characteristics by a remote controller without the added cost and lower reliability of relays or FET switches. The technique can

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Internal MUX allows switching between two different inputs

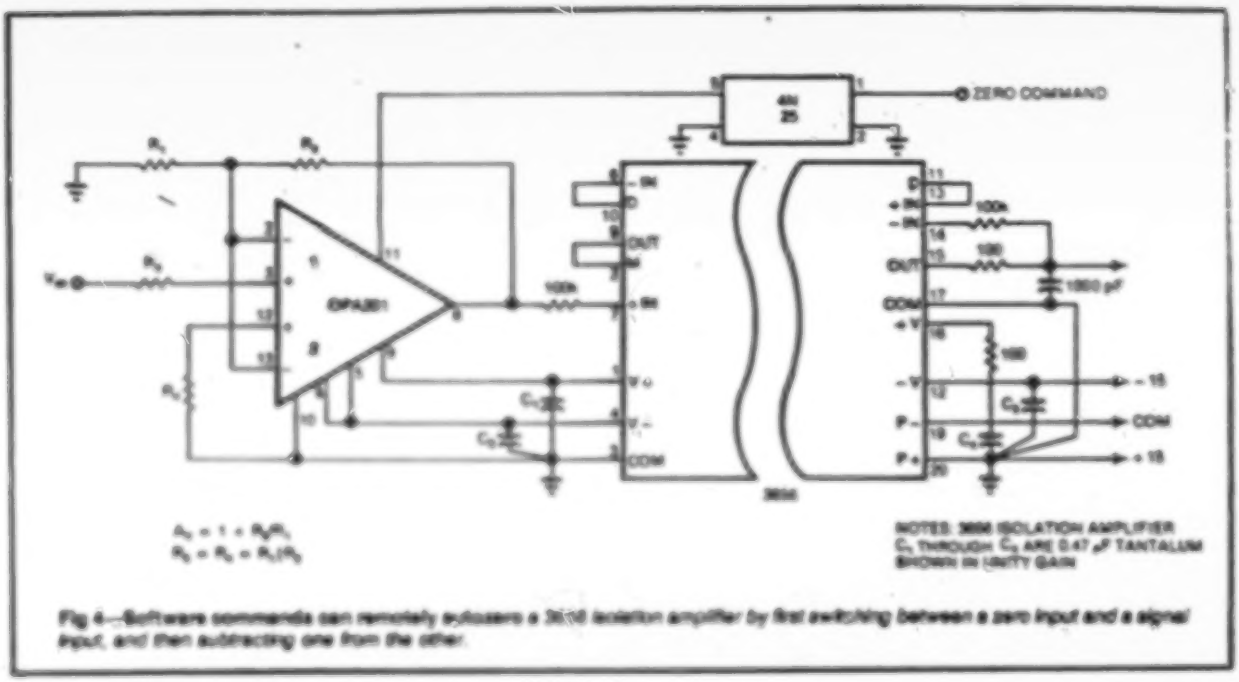

Fig 4—Software commands can remotely autozero a 3656 isolation amplifier by first switching between a zero input and a signal input, and then subtracting one from the other.

also serve to remotely switch in the whole range of such op-amp-based signal-conditioning circuits as summers, compressors, integrators and clamping circuits.

Monitor differential signals, too

Another application area for SWOP amps involves differential signals. Many systems that require remote sensing of analog signals are subject to ac pickup and ground loops, and thus use differential input circuits to reject common-mode errors and noise. The SWOP amp's high gain and CMRR suit it for use in such circuits. Most of the circuits mentioned so far can also serve in differential form, with good rejection of 50- and 60-Hz noise. Additionally, Fig 6 shows a dual-channel, low-power differential amplifier.

If the input impedance available from one SWOP amp isn't adequate, you can employ two SWOP amps and a precision op amp to make a switchable version of the classic 3-op-amp instrumentation amplifier (Fig 7). Using a low-power op amp in the circuit, such as the OPA201, results in an instrumentation amp with dual-input, autozero or selectable-gain features that requires only approximately 1 mA of supply current.

Implement an S/H function

The SWOP amp also functions as a low-power sample-and-hold amplifier that draws only 10% of the supply current required by most S/H circuits. This function proves particularly important where you need remote A/D conversion.

As shown in Fig 8, the S/H circuit calls for only two signal diodes and two capacitors in addition to the SWOP amp. You can, however, add gain resistors to one or both channels for gains other than unity.

The SWOP amp's channel-select pin serves as the S/H mode-control input. When the channel-select input is High (selecting channel 1), the circuit is in sample mode. C_2 charges through the diodes until its voltage

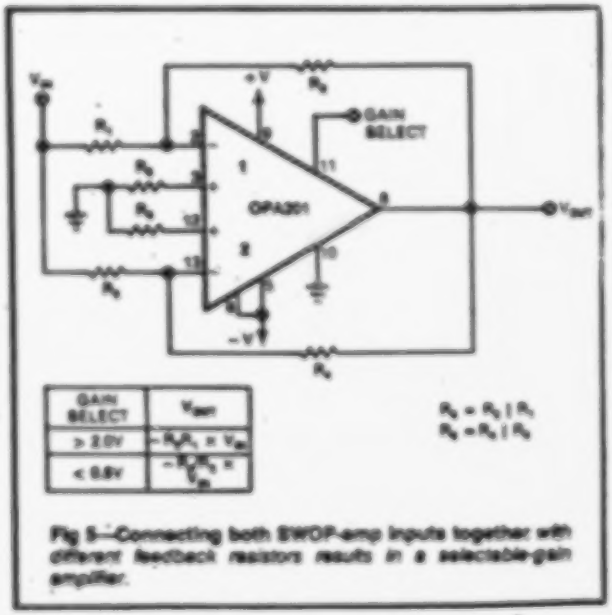

Fig 5—Connecting both SWOP-amp inputs together with different feedback resistors results in a selectable-gain amplifier.

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equals the input voltage. C_1 provides direct high-frequency feedback around the diodes to reduce ringing in sample mode.

Taking the channel-select signal Low selects hold mode. Now the voltage on C_2 provides the input voltage to channel 2, and feedback to channel 2 forces the circuit's output to equal the input voltage present when the hold mode was initiated. The back-to-back diodes now have less than 100 μV across them and disconnect the channel 1 feedback path.

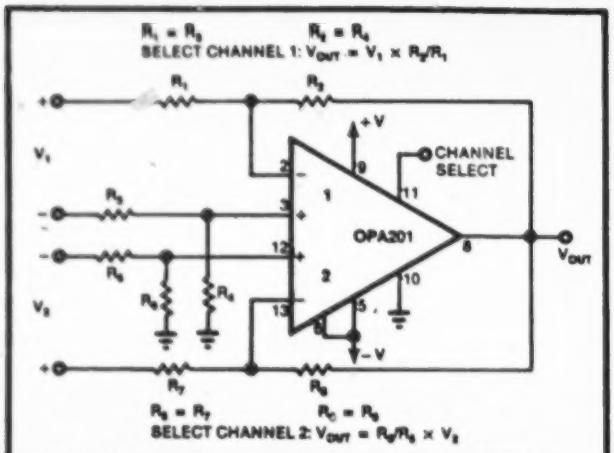


Fig 6—A basic differential amplifier *using the SWOP amp accepts two inputs.*

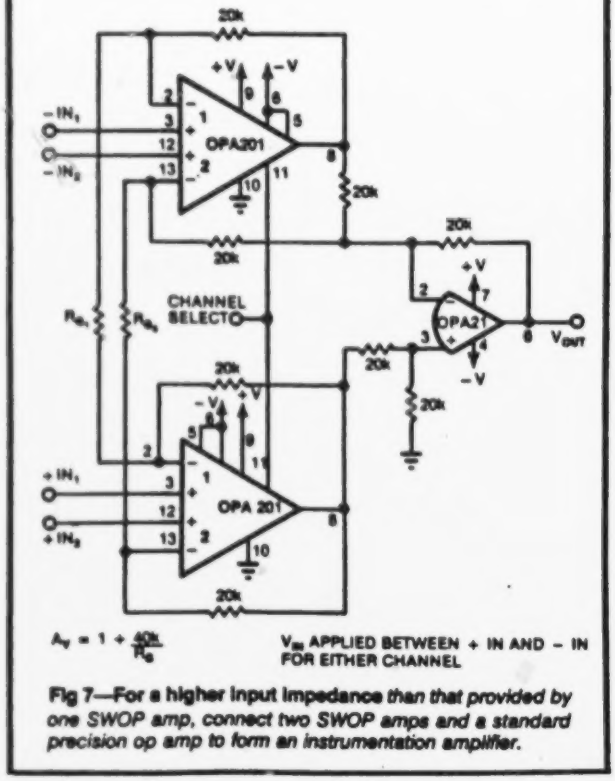


Fig 7—For a higher input impedance *than that provided by one SWOP amp, connect two SWOP amps and a standard precision op amp to form an instrumentation amplifier.*

The input bias current and C_2 determine the circuit's droop, which amounts to less than 2.5 mV/msec for C_2=10,000 pF. This value represents less than 0.1 LSB of droop for a 12-bit, 10V full-scale A/D conversion after holding for 100 μsec.

Additionally, unadjusted zero-scale error is typically less than 1 mV. You can set it to zero using the offset control and one pot by adjusting the hold mode offset to zero, with the input grounded and the mode control signal constantly changing between High and Low. This procedure nulls offset voltage and charge transfer offset.

Aperture time for the circuit equals the time required to switch channels — approximately 7 μsec. Finally, the S/H's slew rate limits acquisition time to approximately 50 μsec for a 10V step. **EDN**

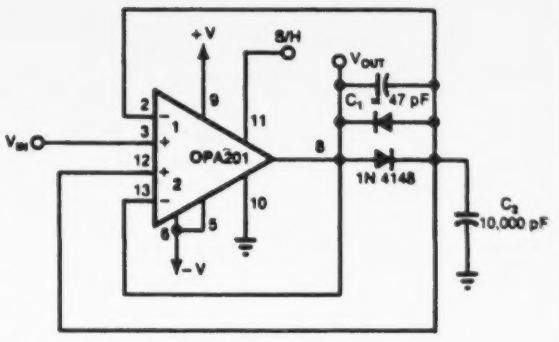
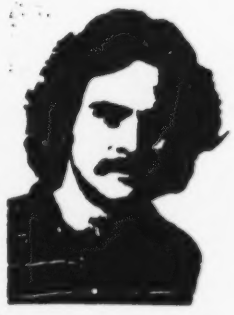


Fig 8—A low-power sample-and-hold amplifier *results from feeding back the SWOP amp's output to one channel.*

Author's biography



Tom Anderson, a design engineer at Burr-Brown (Tucson, AZ), specializes in precision monolithic design. After earning a BSEE from the University of Arizona, he worked as an electronics instructor and a guitar teacher, then joined Burr-Brown six years ago. Tom has applied for a patent on the SWOP-amp-circuit technique. In his spare time he enjoys reading, hiking and music.

Article Interest Quotient (Circle One)
High 479 Medium 480 Low 481

Appendix 2
Schematics for Specific Information Test

Appendix 2A

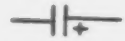
Schematics for Specific Information Test

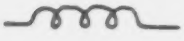
Directions

This test contains 9 items. There is no time limit, but I will record how long it takes you to complete each item.

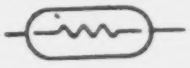
1. Write the name for each schematic symbol.

A.

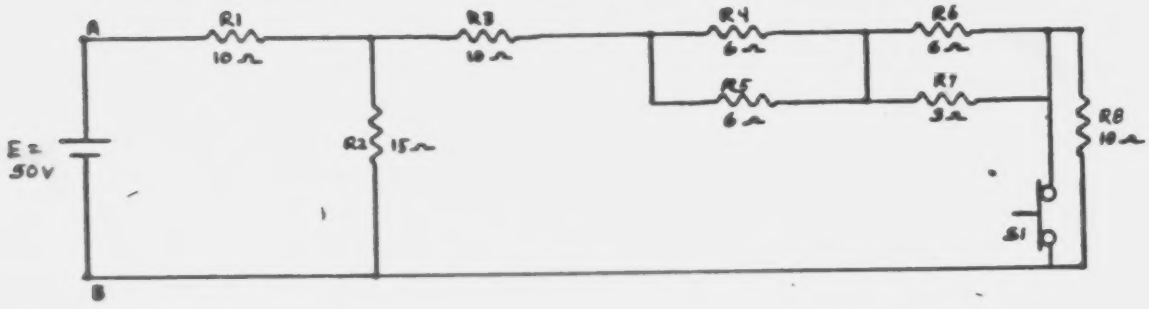
B. 

C. 

D.

E. 

2. What is the equivalent resistance between points A and B?



3. In Figure 5-5 what is the purpose of Q35?

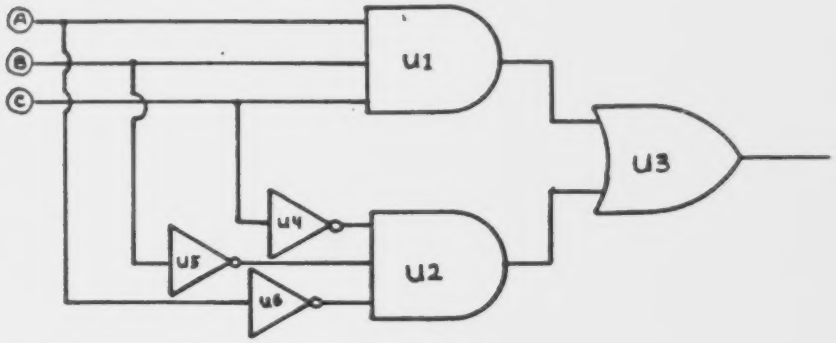
4. In Figure 5-5, what is the magnitude of the positive and negative supplies?

5. In schematic #4, what is the purpose of the lines marked D0 through D7?

6. In schematic #4, list all the components that can drive the lines marked D0 through D7.

SCHEMATICS TEST

7.



A. If A=0, B=0, and C=0, what is the output of U3?

B. If A=1, B=0, and C=1, what is the output of U3?

C. If A=1, B=1, and C=1, what is the output of u3?

8. In schematic #2, list <u>all</u> the receivers of the output signal of U71, pin #3.

9. In schematic #3, what is the purpose of U9 op amp?

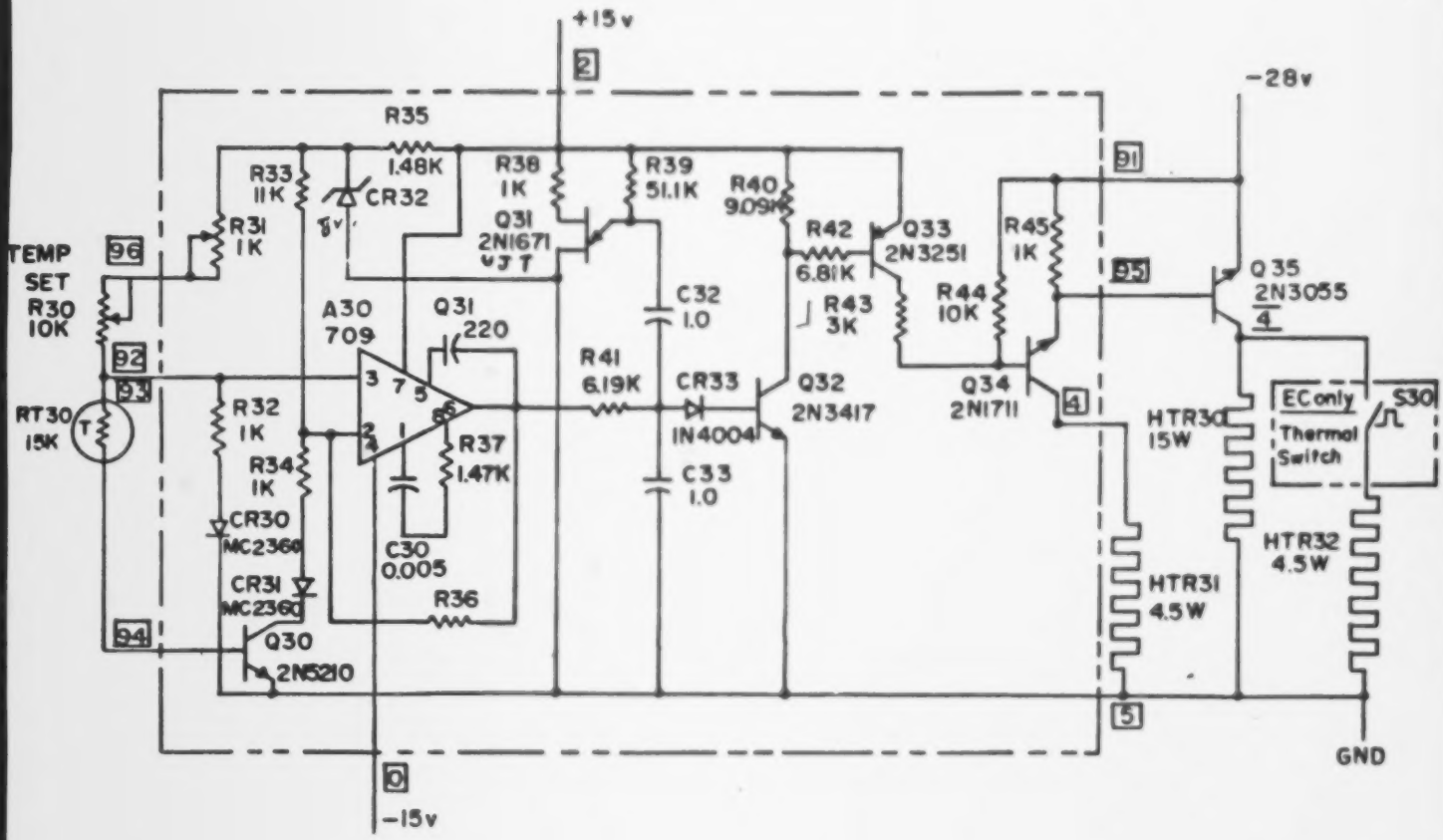

Temperature Controller
+15v
2
-28v
R35
1.48K
R33
11K
CR32
8v
R38
1K
R39
51.1K
R40
9.09K
91
R31
1K
TEMP
SET
R30
10K
96
Q31
2N1671
UJT
R42
6.81K
Q33
2N3251
R45
1K
R44
10K
R43
3K
95
Q35
2N3055
4
A30
709
Q31
220
C32
1.0
92
93
R41
6.19K
CR33
IN4004
Q32
2N3417
Q34
2N1711
4
HTR30
15W
EC only
Thermal
Switch
S30
RT30
15K
R32
1K
R34
1K
R37
1.47K
CR30
MC2360
C30
0.005
C33
1.0
HTR32
4.5W
CR31
MC2360
R36
HTR31
4.5W
94
Q30
2N5210
5
GND
0
-15v

Figure 5-5

#2

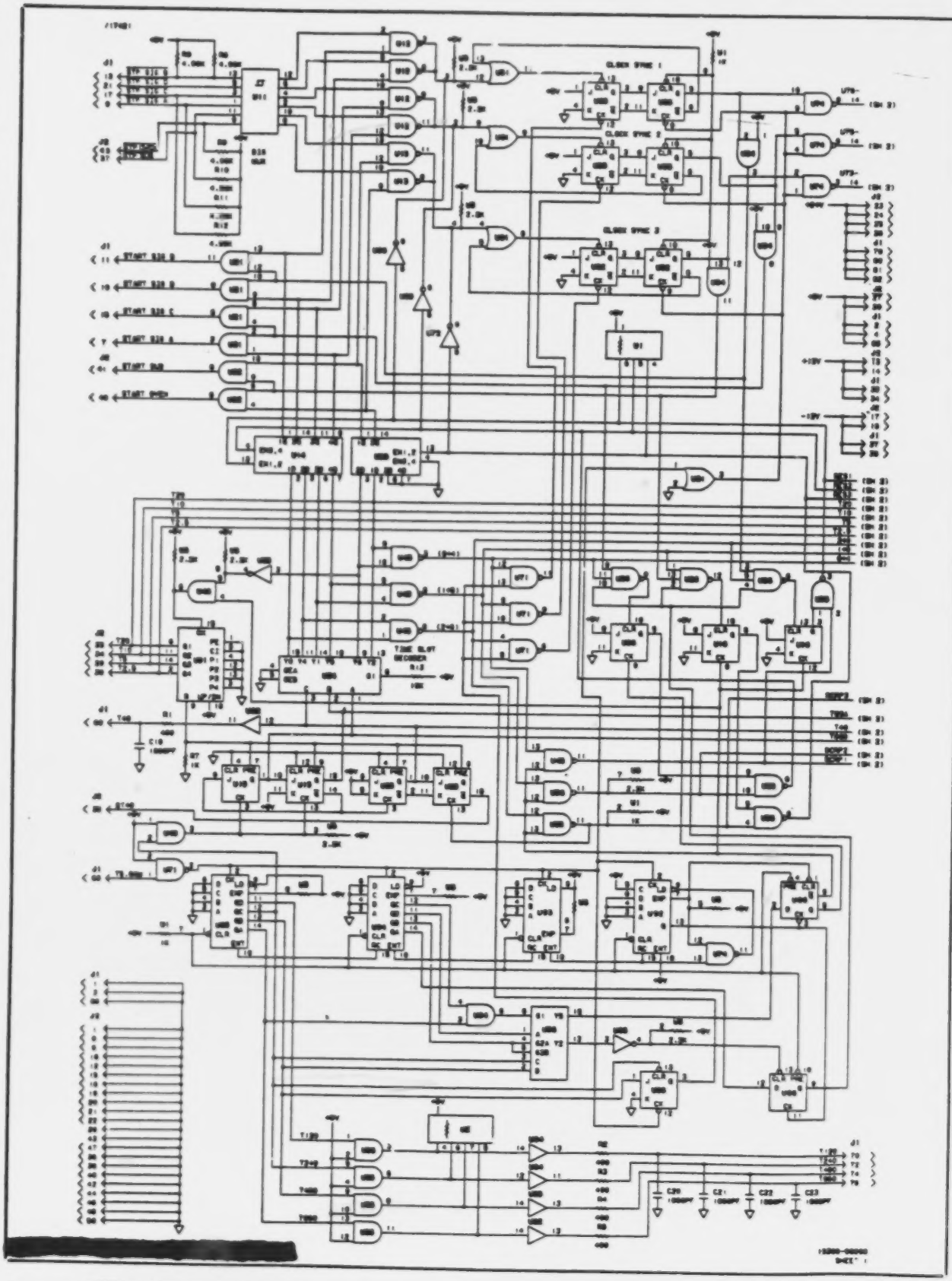


Figure C-31. [redacted]

#2

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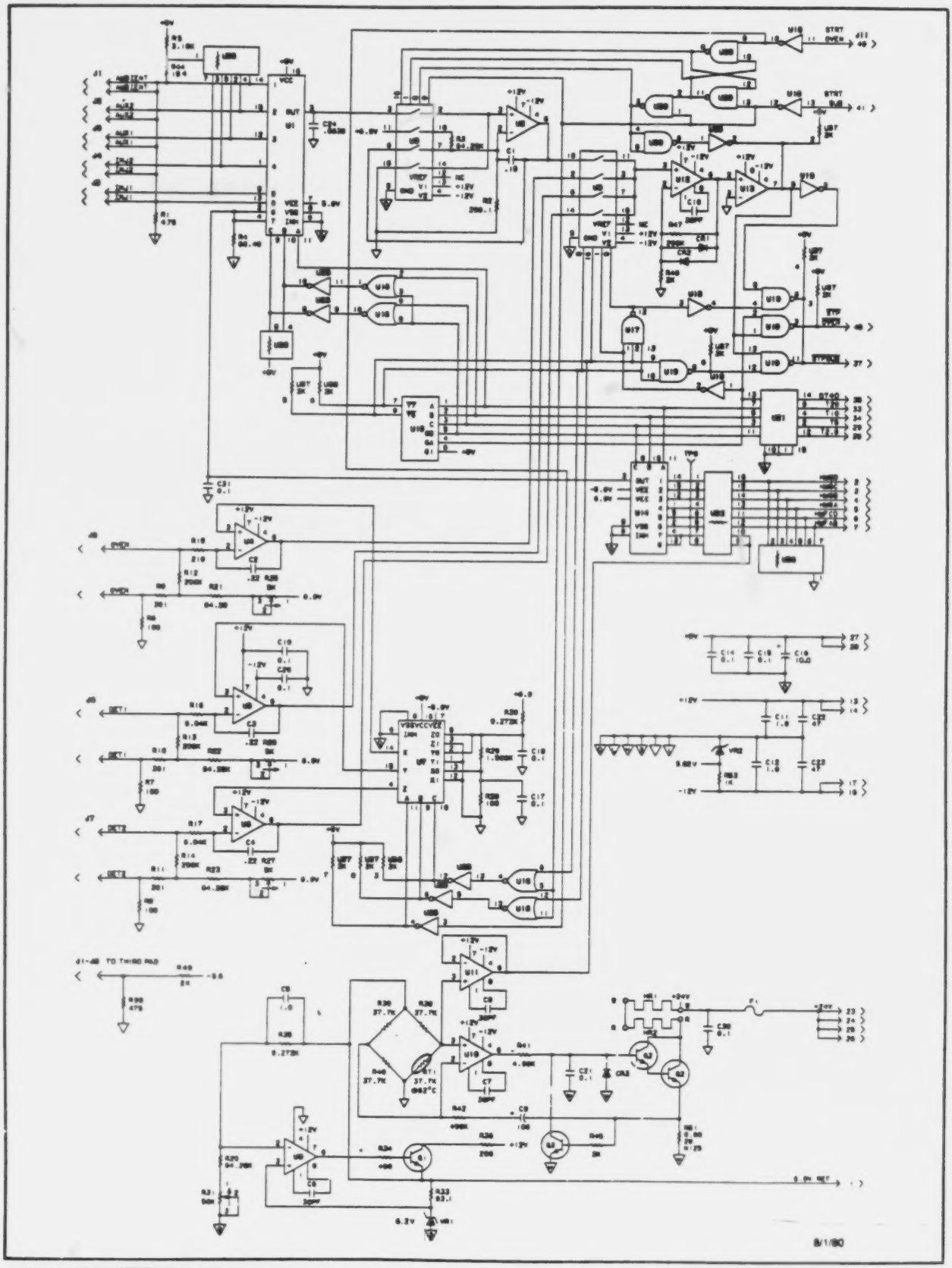

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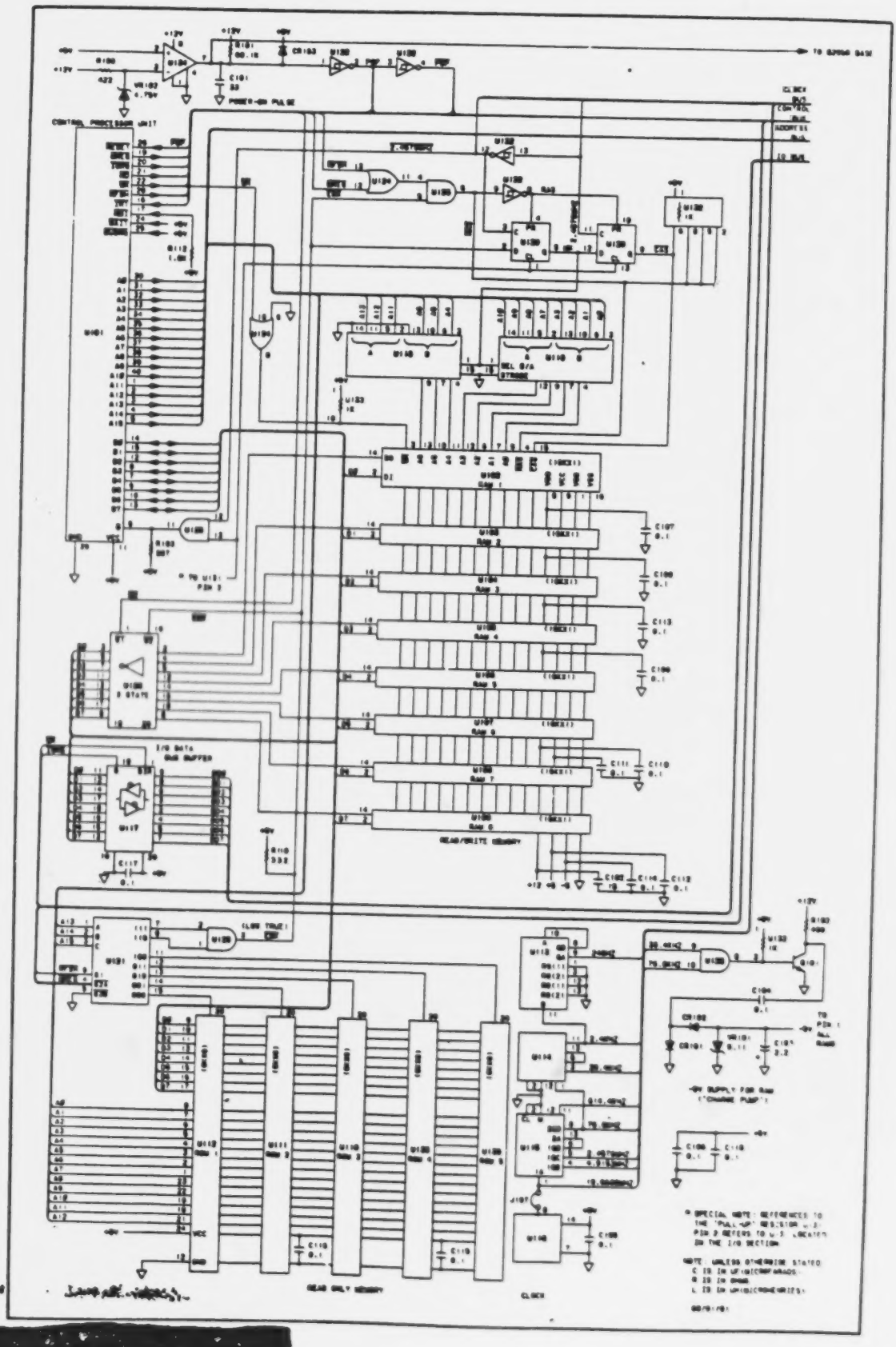
#4



#4

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Appendix 2B

Schematics for Specific Information Test
Answer Sheet

Name: KEY

1. A. resistor
   B. capacitor
   C. inductor or coil
   D. switch
   E. thermistor (or resistor)

2. Rt= 17.5

3. drives the heater current (heater 30 & 32)
   or
   regulates current through heater
   or
   controls temperature

4. 15, 28 (Both numbers must appear at least once in answer; may be positive or negative numbers.)

5. Data bus is bidirectional and carries data to and from CPU
   or
   Data bus--data moves between memories (ROM & RAM) and microprocessor
   ("Data lines" receives score of 1.)

6. U101, U102, U103, U104, U105, U106, U107, U108, U109, U110, U111, U112, U117, U123, U133, U134

7. A. 1 (high)
   B. 0 (low)
   C. 1 (high)

8. U95, U94, U96, U93, U92, U81 (pin numbers optional)

9. provides drive for Q1 for the 6.9 volt reference
   or
   controls the drive for Q1

Appendix 3
Manuals for Specific Information Test

Appendix 3A

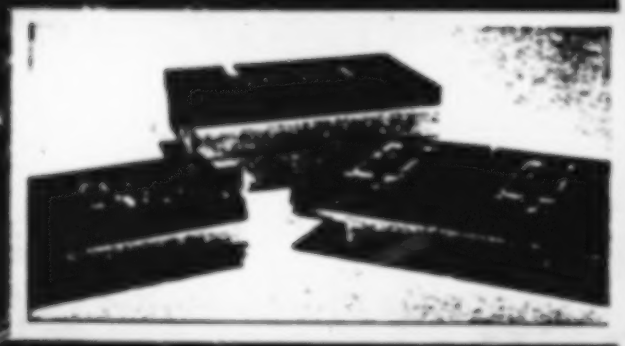
Manuals for Specific Information Test
Sample Question 1 and Related Manual Pages

Test Fixture Assembly and Service Manual

What should be used to remove dirt and dust from the fixture?

Answer: Compressed air (page 14)

Test Fixture Assembly and Service Manual



HEWLETT PACKARD

33

Table of Contents

Introduction 1
Accessories Covered by this Manual 1
Test Fixture and Extender Characteristics 2
Operating Characteristics 3
Recommended Tools and Equipment 3

3

Operation/Service

Table of Contents

Introduction 13
Operation 13
Operation Verification 14
Cleaning the Test Fixture 14
Probe Maintenance 14
Replacing Probes 14
Adding Probes 15
Replacing Sockets 15
Replacing the Gasket 16
Troubleshooting 16

Operation Verification

After mechanical operation of the test fixture is verified, an electrical verification should be performed. For the 3060A System, use the Test Fixture Verification Software, part number 03060-80056.

Cleaning the Test Fixture

To clean the test fixture, remove the locking screws to open the fixture, then use compressed air to remove dirt or dust. Clean the outside as well as the inside.

Also, periodically wipe off the top plate of the fixture using alcohol.

Probe Maintenance

After a large number of PC boards have been tested, the probes may get dirty or wear out. The number of PC boards that are tested before this occurs will depend on how clean the PC boards are, the type of probe being used, and the type of leads on the boards. Periodically inspect the probes to assure that they do not need to be cleaned or replaced.

Replacing Probes

CAUTION

Using probes other than those sold with these test fixtures can damage the sockets.

If a probe is damaged or a different type of probe needs to be installed, first turn on the vacuum with a PC board installed. Open the fixture and place a spacer (1251-4598) around at least six guide posts. Now when vacuum is released the probes will remain exposed. Use the probe/socket removal tool (8710-1479) to pull the probe out of the socket (refer to Figure 3-1). Then, reinstall the PC board and apply vacuum to remove the spacers. Then install the new probe using the probe insertion tool (8710-1478).

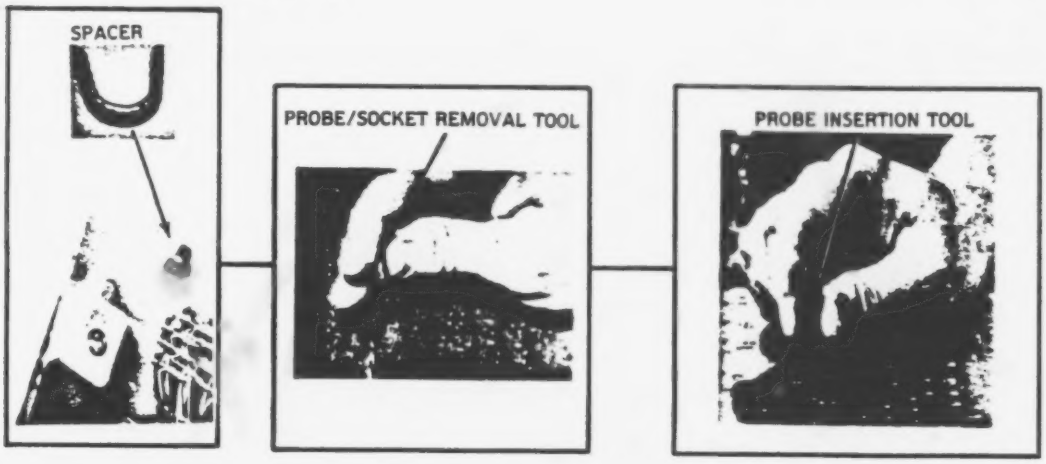


Figure 3-1. Replacing Probes

Appendix 3B

Manuals for Specific Information Test
Sample Question 2 and Related Manual Pages

3390A Reporting Integrator

What is the voltage range of the programmable voltage power supply?

Answer: +3 to +11 (page 23)

Service

Reporting Integrator

339DA

HEWLETT PACKARD

Contents

A. GENERAL INFORMATION

Identification 1
Specifications 1
Accessories 2

B. PERFORMANCE CHECKS

Self-test and Parameter Initialization 3
Zero Volt Signal Input Test 3
One Volt Signal Input Test 4
Internal Noise Checks 4

C. ADJUSTMENTS

Opening/Closing the Integrator 7
Electrical Adjustments 10
AC Line Voltage Selection 10
Power Supply Adjustment 11
Print Head Drive Movement 11
Plot Dot Intensity 12
Mechanical Adjustments 13
Printer Belt Tension 13
Out-of-Paper Sensor Alignment 13

D. TROUBLESHOOTING

Trouble Symptoms 15
Power-up Problems 15
After Power-up Problems 15
Printer/Plotter Problems 16
Corrective Procedures 17
Power Supply Loading Check 17
First Case Paper Feed Problems 17
Second Case Paper Feed Problems 17

E. SERVICE

Functional Theory 21
Keyboard 21
Main PC Board 22
Power Supply 23
Transformer 24
Fuse 24
A/D Converter 27
CPU-Memory-Clock 32
I/O-Interrupt-Keyboard 37
Printer/Plotter Control 39
Main Board Removal and Parts 43

E. SERVICE (cont'd)

Printer/Plotter Assembly 43
Removal of the Printer Assembly 43
Replacement of:
Print Head Drive Belt 44
Platen 45
Print Head Assembly 45
Paper Advance Motor 47
Microswitch Assembly 47
Print Head Drive Motor 47
Out-of-Paper Sensor 48
Pinch Rollers and Tension Clips 48
External I/O Board (OPTIONAL) 51

F. CABLES

Signal Cables 55
Remote Start/Stop Cables 56
Remote Start/Stop Option 19401A 57
RS-232C Data Comm Cable 57

G. SAMPLER/ EVENT CONTROL MODULE

S/ECM Specifications 59
AC Line Voltage Selection 59
Troubleshooting 60
Service 61
Main Board Removal 61
Functional Block Description 61
Power Supply Adjustment 62
Theory of Operation 62
Parts List 64

APPENDIX 1

Installation of External I/O Board Kit 71

POWER SUPPLY

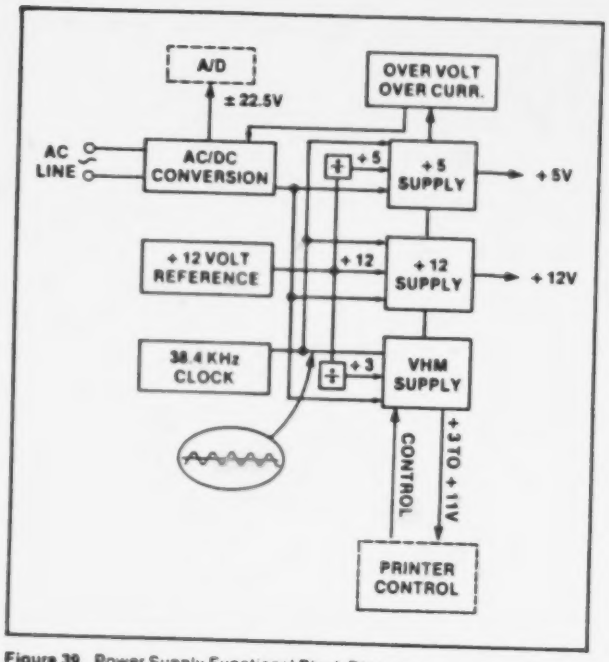


Figure 39. Power Supply Functional Block Diagram

AC to DC Conversion

The input AC line voltage (100,120,220, or 240) is converted to provide three separate raw DC supply voltages of + 25 volts and ± 22.5 volts (with center tapped secondary winding). Two grounds are provided, one the main system ground (25V supply) and the other a floating ground for the ± 22.5V A/D supply. A floating ground is employed on the "front end" of the A/D Converter to reduce ground path circulation currents. The potential of the A/D floating ground will match the potential of the chromatograph's ground. (NOTE: all three supplies are "raw", i.e. unregulated.) The AC line fuse provides input current overload protection to the entire instrument.

Supply Regulators

Three regulator sections are used to supply regulated + 5, + 12, and VHM voltages to the instrument. (The VHM supply is used exclusively by the Printer/Plotter Control section.) Each regulator section provides over-current and over-voltage sensing which triggers a crowbar circuit to "blow" the AC supply fuse. Each supply will deliver a maximum of 5 amps current at their respective voltages. (NOTE: There is no over-voltage protection on the VHM supply.)

Over-Voltage, Over-Current Protection

If the over-voltage, over-current trigger is enabled by any of the three regulators, the 25 volt is shunted to ground (crowbar) and held at ground until the line fuse blows. An over-voltage condition is caused by an increase of the + 12 volt or + 5 volt supply outputs. An over-current condition is caused by excessive current loading of the power supplies by the 3390A instrument.

Theory of Operation

The 3390A utilizes a pulse-width-modulated (PWM) switch mode power supply to provide main power. The supply has three independently regulated outputs consisting of + 5V, + 12V, and programmable voltage supply (VHM). The VHM output can be programmed to any of eight voltages, ranging from + 3 to + 11.0 volts, via a 3-bit digital-to-analog converter (DAC) at its input. All three switching regulators are synchronized to run at 38.4 KHz. However, the duty cycle of each is different because it is proportional to the output voltage. The basic scheme of regulation is dependent on this duty cycle. Variations in line and load cause the duty cycle to change accordingly to maintain constant output voltage.

The main secondary of the transformer T301 uses a full wave bridge rectifier and input filter capacitor (C308/9) to obtain a nominal 25 volt DC bus. This single bus provides operating voltage for the regulators and at the same time supplies power for their associated outputs. The rail voltage has some ripple and changes with variations in line voltage, but as long as it is between 18 and 36 volts, outputs remain within specifications. The following explanation focuses on the + 5V supply. However, the scheme is the same for all supplies.

U301(8,9,10) is an op-amp wired as a non-inverting amplifier to provide a stable 12V reference. R312 and R311 divide this down to 5V for use as the + 5V supply reference. U301(12,13,14) is an op-amp monitoring the + 5V output comparing it against the reference. It amplifies the difference producing an error voltage to the non-inverting (+) input of comparator U302. The inverting input (−) consists of a 38.4 KHz triangle wave (shaped from the square wave clock by C304). When U302 compares the error voltage against this triangle wave, it produces a 38 KHz square wave at its output with a duty cycle that is proportional to the level of the error signal. Transistor switch Q301 is turned on and supplies power to the output for the duration of the low-true duty cycle. When Q301 turns on, the 25 volt output rail is applied to the output filter L301 and C301; because of this filter, the output cannot rise instantly to 25V. Rather, it rises just enough to maintain the + 5V output. To see how the loop control works, assume that because of a sudden change, the output voltage tries to go low. U301(12,13,14) senses this change and produces a lower level error voltage. This means more of the triangle wave will be above this error voltage level; therefore, the duty cycle out of U302 will increase. This will tend to increase the output voltage to again maintain it at + 5V. The same thing happens if, instead of a load change, the rail goes down. Conversely, the duty cycle would decrease if the output voltage tried to increase. Thus, the duty cycle increases or decreases according to load and rail perturbations to maintain a constant output voltage. R301 is used for sensing current. If the current goes above 5A, it causes a .6V drop across R301 causing Q305 to turn on. This pumps current into R327 and triggers Q309 causing the 25V rail to be shorted to ground. Q309 holds this until the fuse blows.

Index

Adjustments 7
A/D Converter 27
A/D EMI Shield 29
AC Line Voltage Selection 10
AC Supply Conversion 23
Accessories 2
Attenuation, Full Scale Voltage 5

Cable(s), 3390A to S/ECM 70
Cable(s), Data Output 57
Cable(s), Power 2
Cable(s), printer/plotter 44, 48
Cable(s), remote start/stop 56
Cable(s), RS-232C 57
Cable(s), sampler 70
Cable(s), signal 55
Case Opening Tool 8
Case, closing 9
Case, opening 7
CLOCK 32
Corrective Procedures, paper feed 17
Corrective Procedures, power supply loading 17
CPU 32

DC supply voltages 23

EMI Shield 29
External Event Control 62
External I/O Board 51
External I/O Board, installation 71
External I/O Board, remote printer baud rate 72
External I/O Connector 51

Fuse 10, 24

I/O Bus Buffer 32
I/O Decoding 37
Input Signal Connector 32
Internal Noise Check 4
Interrupts 37

Keyboard 21, 37

Line voltage selection 10

Main PC Board 22
Main PC Board, removal 43
MEMORY 32
Memory addresses 33
Memory timing 33
Microswitch Assembly 47

Noise Limits 5

One Volt Input Signal Test 3
OOPS 37, 48
OOPS Sensor Alignment 13
Ordering Options 2
Over-current protection 23
Over-voltage protection 23

Paper Advance Motor 39, 47
Paper Compartment Door, removal 7
Paper Feed Problem 17
Parts, 3390A 43
Parts, printer/plotter 49, 50
Parts, S/ECM 69
Performance Tests 3
Pinch Rollers 48
Platen 45
Plot Dot Intensity 12
POP 32
Power Supply 23
Power Supply Adjustment 11
Power Transformer 24
Print Head Assembly, adjustment 46
Print Head Assembly, replacement 45
Print Head Drive 39
Print Head Drive Belt 44
Print Head Drive Duty Cycle 11
Print Head Drive Motor 47
Print Head, resistance 39
Printer Belt Tension 13
Printer/Plotter Assembly 43
Printer/Plotter Control 39
Printer/Plotter Illustrated Parts Breakdown 49
Problems, after power-up 15
Problems, power-up 15
Problems, printer/plotter 16
Problems, S/ECM 60
Problems, troubleshooting 15

RAM 32
Remote printer 51
Remote Start/Stop Box 57
Remote Start/Stop Cables 56
Remote Start/Stop, 3390A 51
ROM 32
RS-232C 51

S/ECM 21, 51, 59
S/ECM BCD/LED Assembly 68
S/ECM case opening 59
S/ECM External Event Connector 68
S/ECM Fuse 60
S/ECM Line Voltage Selection 59
S/ECM MCU 63
S/ECM Remote Start/Stop Connector 68
S/ECM sampler cables 70
S/ECM Service 61
S/ECM specifications 59
Sampler Control 62

Appendix 4
Articles for Specific Information Test

Appendix 4A

Articles for Specific Information Test
Sample Item 1

Question: Name one condition (environment) in which thermal printers will not function efficiently.

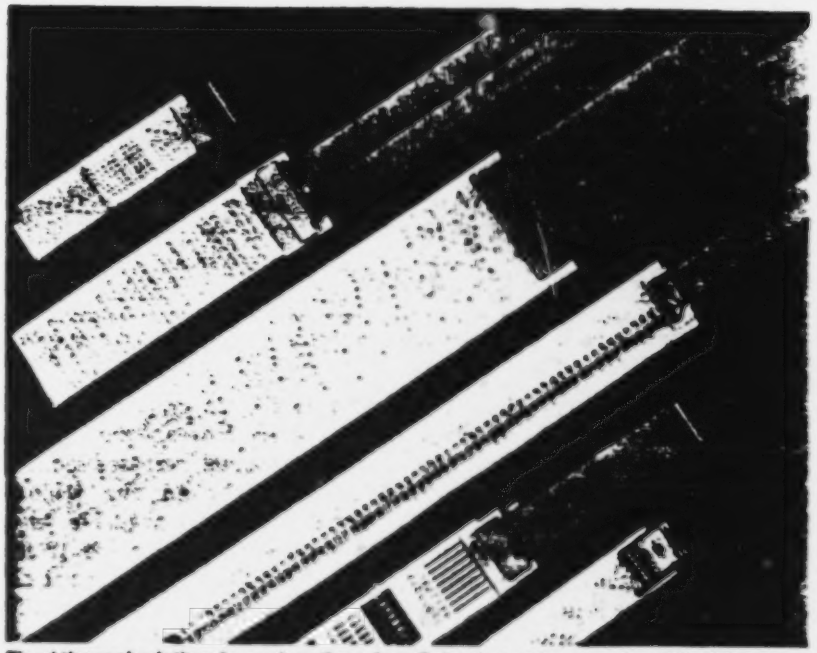
Answer: 100+ Farenheit temperatures (page 60).

Sophisticated OEM printer mechanisms expand system-design options, lower costs

Ed Teja, *Western Editor*

Buying a printer mechanism rather than a complete stand-alone printer does more than save packaging costs: You can harmoniously integrate a printing mechanism into your system, choosing the size, shape, performance and even the printing technology that best meets your system requirements. Because of these choices, a prepackaged component no longer has to dictate the shape and form of your end product.

But choosing a printer mechanism doesn't mean you're limited by a standardized product. Indeed, these mechanisms are much better suited to customization than stand-alone printers. Alterations in packaging, paper-feed path and the mounting of the heads or ribbon are all possible at this subsystem level.



Fixed thermal printheads, *such as these from Gulton Industries, span the width of the paper, eliminating the need for a mechanism that positions the head and thus improving reliability.*

Where there's heat...

The majority of OEM printer mechanisms relies on thermal printing technology in one of two forms: direct thermal printing and thermal transfer. With direct thermal printing, heating elements produce the characters on special thermal paper. Thermal transfer uses a heat-sensitive ribbon and thermal printheads to transfer an image onto plain paper. Both methods silently provide a clear printed image with contemporary heads that allow dot resolutions to reach 300 dots/in (dpi).

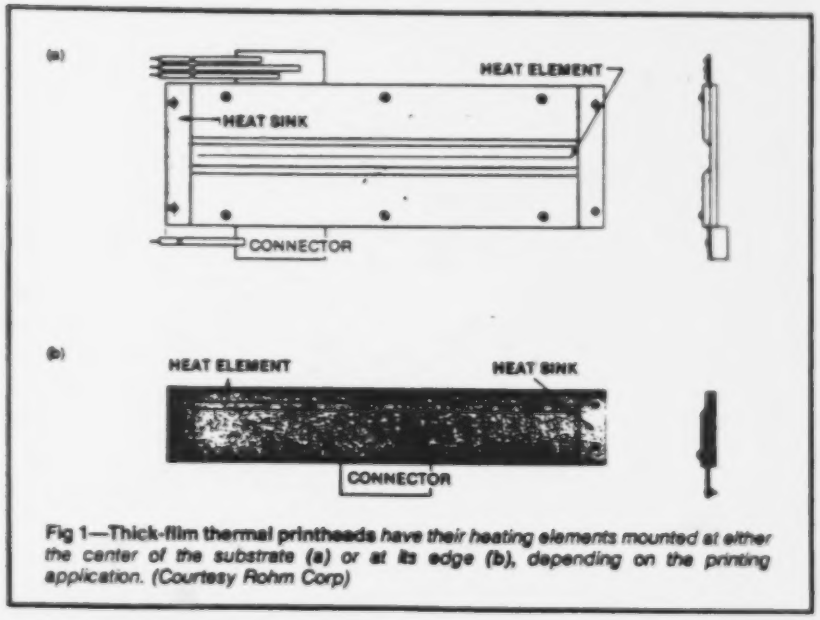
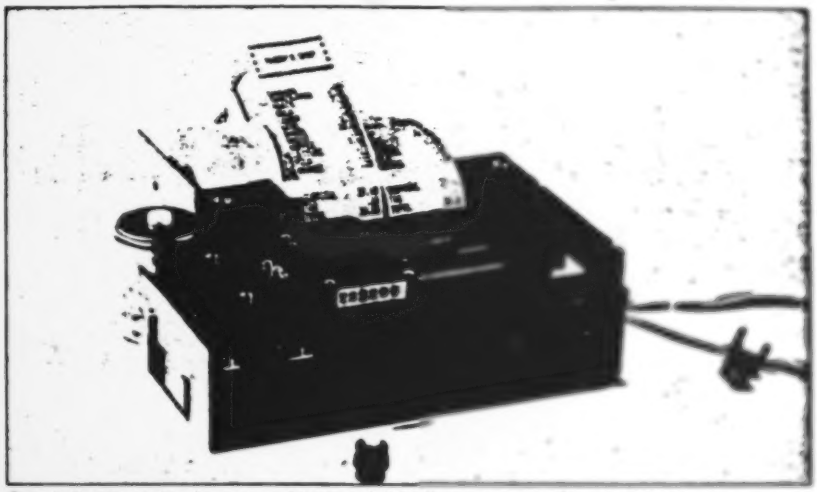


Fig 1—Thick-film thermal printheads *have their heating elements mounted at either the center of the substrate (a) or at its edge (b), depending on the printing application. (Courtesy Rohm Corp)*

Thermal printers are typically used to provide hard copy in applications where the printers must be exceptionally quiet. In fact, medical equipment and many office machines sell more easily if they don't contribute to the rising noise level that accompanies automation. The medical industry, for example, almost exclusively uses thermal printing.

Rohm Corp makes a variety of thermal printhead subsystems that form the basis of a thermal printer. For starters, the firm makes the



Specialized mechanisms provide special features *to meet less common system needs. Westrex's Model 82 printer features a split platen to print original journal and receipt copies simultaneously.*

two types of thick-film printheads (**Fig 1**): center-mounted and edge-mounted heat elements. Note that the position of the heating element is a good indication of the printhead's performance and its intended application. For instance, by positioning the heating elements in the center of the printhead, the manufacturer gains greater control over its fabrication. Thus, center-mounted elements cluster the matrix dots as close as 300 dpi, which provides greater detail in printouts. To achieve this 300-dpi printing density, Rohm mounts the driver and logic circuits in 40-pin ICs directly on the printhead substrate.

In contrast, mounting heating elements at the edge of the printhead makes it more difficult to achieve the dot densities of center-mounted types (typically 200 dpi max). Printing at the edge, however, lets you see the printout as it's printed, which proves particularly important in vital recorder applications such as medical strip charts.

Printhead width matches paper

Rohm Corp's edge- and center-mounted thick-film printheads range from 2 to 17 in. in width, allowing you to design a printer with a fixed head that's the full width of the paper. Because the head never moves, the design reduces noise and increases reliability. And although the widest thermal printheads available on a single piece of ceramic are 17 in. wide, Rohm Corp offers special 22- and 24-in. configurations especially suited for CAD/CAM applications. In such systems, thermal-transfer printing costs less than the electrostatic printing previously used, according to Bob Peckham, Rohm Corp's product manager.

One especially sound advantage of using thick-film printheads is that they make it simple to put together a rudimentary printer. You don't need a mechanism to move the head. All you need is a way of moving the paper under the head, which often requires little more than a stepper motor and a rubber wheel that actually moves the paper. A typical thick-film, center-mounted 8½-in.-wide printer mechanism that places 240 dpi sells for $450 (1000); a 200-dpi version costs $325 (1000). An edge-mounted, 100-dpi, 8½-in.-wide unit from Rohm costs $325 (1000).

For more difficult printing assignments such as printing oversized characters, curves and lines, Rohm also makes thin-film serial printheads. These printheads consist of a single row of heating elements that prints in 1×7, 7×1, 1×9, 1×16 and 1×24 dot matrices. Typical prices, including flex cables, are $25 and $30 (1000) for the 1×9 and 1×16 units, respectively. The cutaway diagram in **Fig 2** illustrates the printing element's construction. The serial printheads connect to a flexible cable and mount on a moving head assembly that allows you to position the head over any spot on the paper.

Specifying complete subsystems

While the idea of using a printer mechanism seems appealing, you might not feel the same about having to design your own controlling electronics. Luckily, just because you don't want to buy a stand-alone printer doesn't mean that you have to design one from components.

For instance, Fujitsu America Inc sells two thermal-printer assemblies

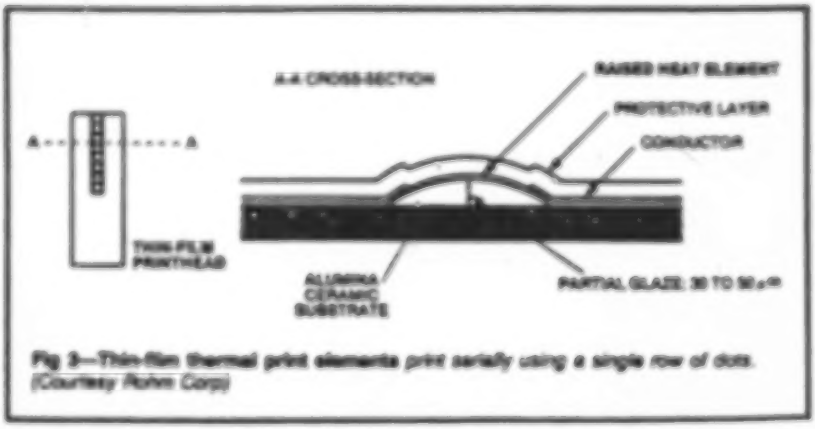


Fig 3—Thin-film thermal print elements *print serially using a single row of dots. (Courtesy Rohm Corp)*

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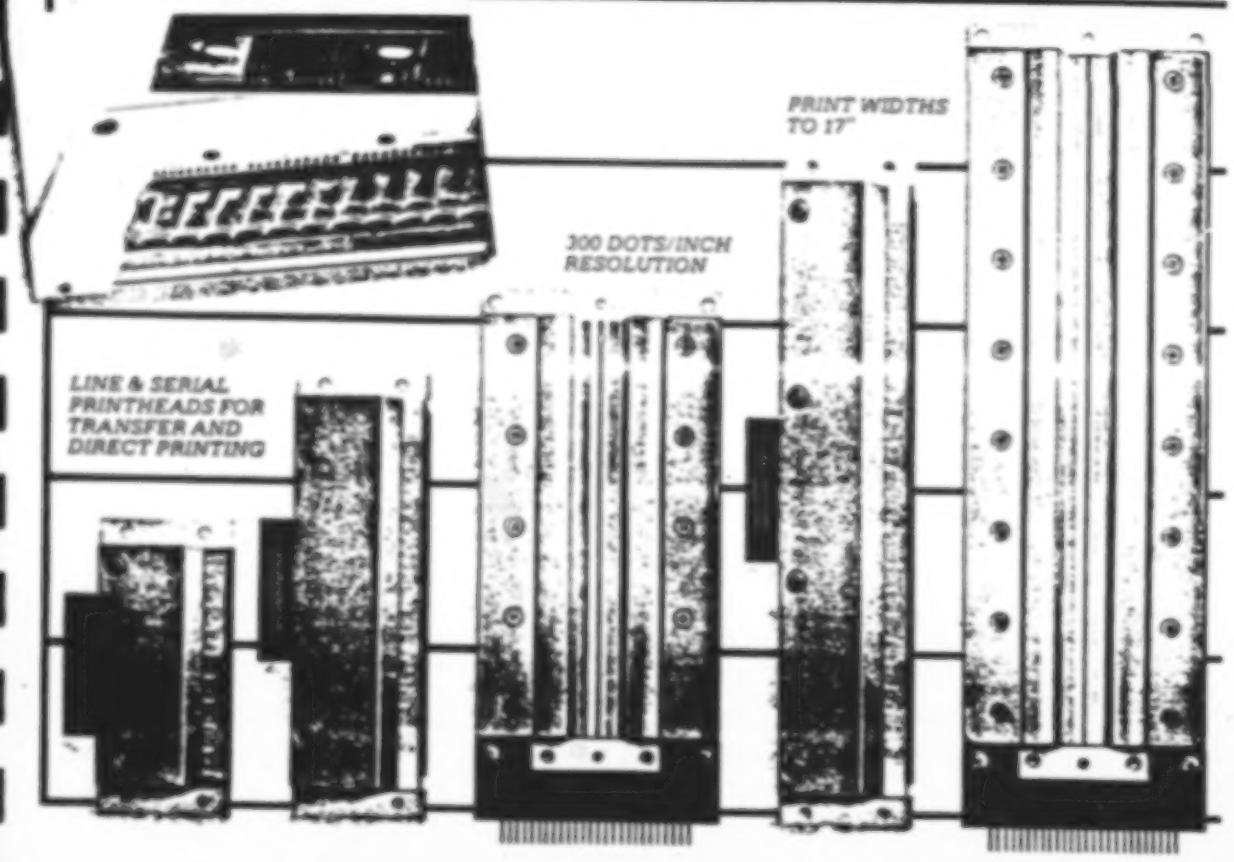

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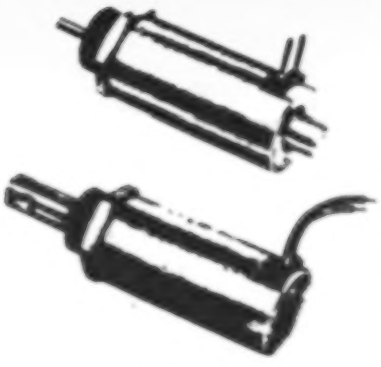

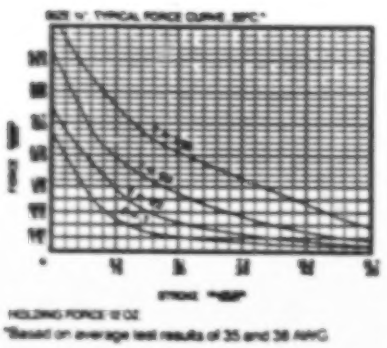

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and separate controller cards to give you a choice of 20- or 40-column thermal printing. Using a fixed printhead with edge-mounted elements, both the 20-column Model FTP-020UC ($160 in OEM qty) and the 40-column FTP-040UC ($200 in OEM qty) place 70 dpi to create 5×7-dot characters. Both print at 80 cps.

The printer has a simple interface that is nonstandard. If you are going to use the printer with a conventional host computer system, then you might prefer something a bit more familiar. When you add the appropriate controller as shown in Fig 3, the host can talk to the printer via a standard 8-bit parallel (Centronics) interface. Either way, you acquire the advantages of a thermal printer in an easily configurable package.

Gulton Industries Inc also offers thermal-printer subassemblies from low-cost 20-column mechanisms to more specialized units. The $260 (100) Model Gap-132M, for example, is a linear-array graphics printer mechanism. It outputs 132-dot linear arrays in 11 columns on 2.2-in.-wide paper.

Without leaving the realm of printer mechanisms, the firm adds a few sophisticated embellishments that minimize your design time. The $595 (100) Model 4100, for example, suits a wide range of applications. It provides all the features you'd expect from an analog recorder—it accepts analog inputs directly—and outputs the data along with customized messages or annotations stored in the unit's firmware. This touch makes any system's printouts more readable and better looking. "The end user judges the final product by the printout," contends Gulton's marketing manager John Olobri. "You should make sure that the printout represents your product fairly."

In addition to refining the appearance of the printed output, Gulton has tried to make the recorder module easy to use. The interface is simple, rather than sophisticated, to ease the software burden that complex control schemes place on the host computer.

Making an impact on printing

Although thermal printers have their advantages, they might not suit all applications. For instance, if you require high volumes of printed output, the price of thermal paper or thermal-transfer ribbons can

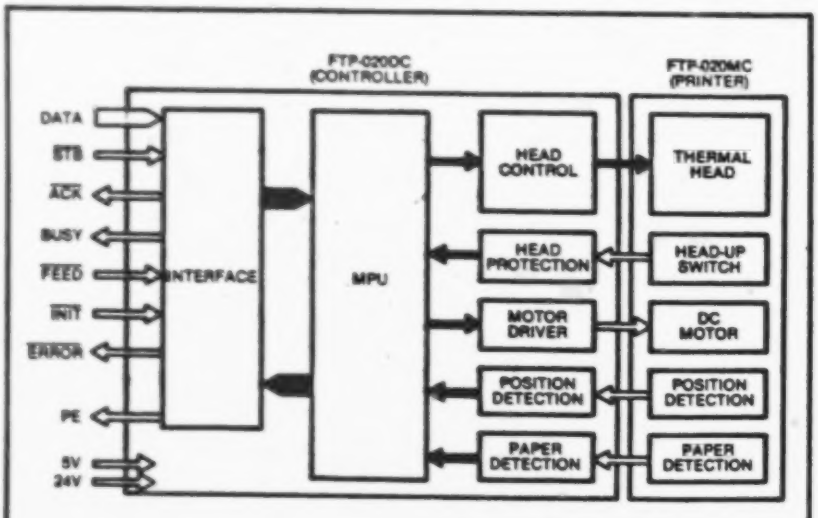

Fig 3—Adding the optional controller to Fujitsu's thermal printer lets you interface to the printer via a standard Centronics parallel port.

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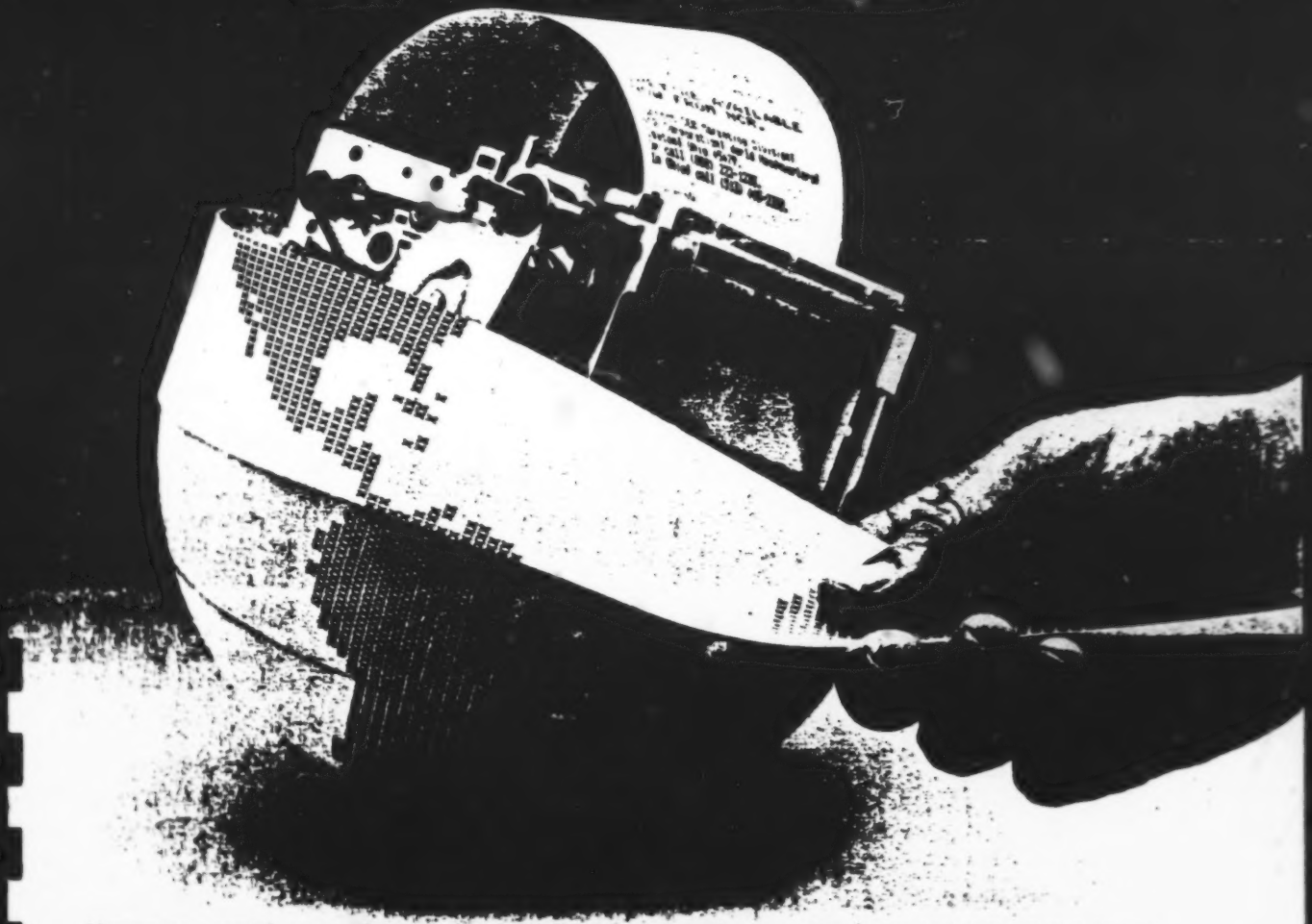

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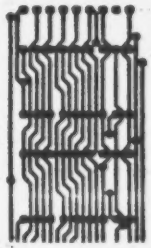

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TECHNOLOGY

begin to make a difference in the cost of ownership of the system.

Furthermore, thermal printing won't work well in all environments. A thermal printer might have difficulty providing readable copy in +100°F temperatures. If your customers require systems that must operate in harsh environments, like the automatic-teller machines (ATMs) used by banks or the field-service machines used with gas pumps, then you might want to consider using an impact printer.

The most recent impact-printer mechanisms prove both price and performance competitive with thermal printing units. For instance, Hi-G's 80-column mechanisms begin at less than $300 (OEM qty). The company's basic impact-printer design involves three independent stepper motors: one positions the paper, one moves the head and the third controls the ribbon. The 3-motor approach is more complex than thermal printers, but it also allows for high-speed and specialized printing. You can make the printer do whatever you want it to.

Hi-G's approach gives the firm the opportunity to create exactly the printer you need. With changes in the firmware and hardware, users can configure Hi-G's printer mechanisms to meet so many system specifications that the firm seldom sells any standard products. The models illustrated in its catalogs are only representative of the potential printer components.

When selecting a printer mechanism, the complexity of the paper path is one key item that OEM system designers should consider. Many point-of-sale terminals have printers with paper paths that are too complex. Changing paper, especially the widely used 3½- to 3⅞e-in. paper rolls, can take an inordinant amount of time. Because simple operator use and maintenance are important criteria when selecting a component and go a long way towards making your system acceptable to an end user, firms like

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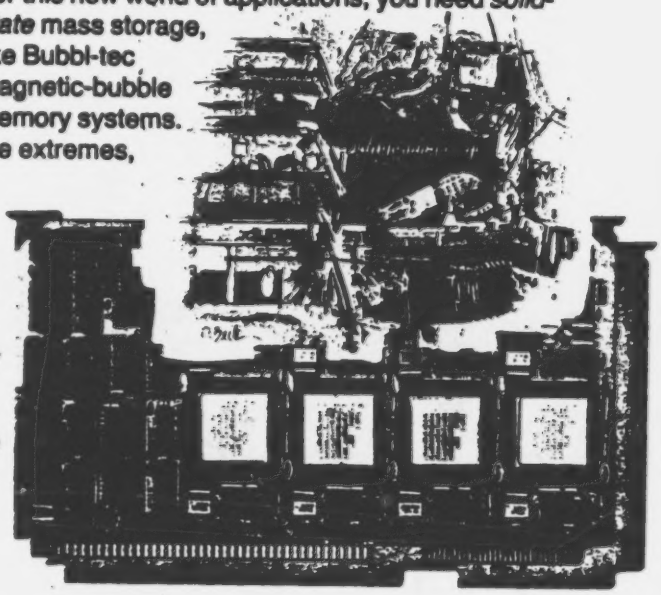

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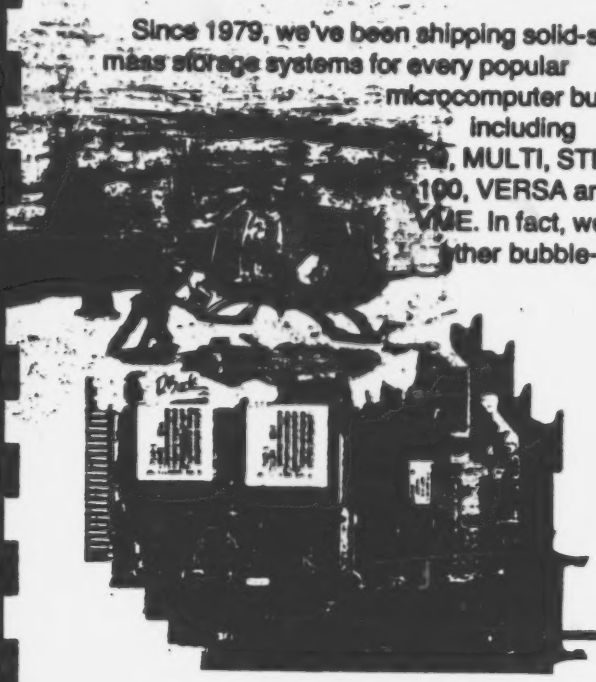

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62

TECHNOLOGY UPDATE

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Hi-G expend much design effort to simplify the paper path and the paper-changing process. Hi-G's print mechanisms for 3½- and 3⅞-in. POS applications begin at less than $200 (OEM qty).

Meanwhile, NCR's 40-column Answer printer family uses impact printing to furnish reliable multiple-copy outputs. For cost-sensitive applications, Model 2199 prints 40 columns of 7×7-dot characters at 120 lpm. In large OEM quantities the printer costs less than $100. For higher performance at only slightly more expense, Model 2285 delivers copy continuously at print speeds to 200 lpm. And you get more than higher performance for your money. The Model 2285 provides three to four times the reliability of the cheaper Model 2199.

Printer reliability is critical

Because much of the firm's market lies in unattended point-of-sale terminals and field-service machines, NCR focuses heavily on the issue of printer reliability. Product manager Barry Moellman contends that there are many ways to characterize a printer's reliability. You can cite the expected life of the printhead, the MTBF of the stepper motors or a host of other important statistics. But the only statistic that is truly and consistently measurable is the length of time the unit prints before experiencing a problem. Objective measurement requires empirical testing—a significant sample of printers printing. Thus, a printer's reliability is more than the life of its head. It includes the tendency of paper to jam in its path or of the ribbon cartridge to fail. In an unattended field-service machine, anything that stops the printer from providing customers with receipts is considered a printer failure.

If your application has special requirements, such as the need to print two original receipts at the same time, then you might want to consider the printer mechanism line from Westrex. Model 82 is a 100-cps, 18-column mechanism that costs $98.40 (250 to 499). In addition, the firm offers a selection of slip/document-mechanisms journal printers. It will even sell just the 7-pin printhead (Model 801) for $55 (100 to 249) to OEMs that are serious about building a custom printer.

With choices such as these, there's really no excuse for not using the optimum for your application, budget and design time. **EDN**

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(Circle One)
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Appendix 4B

Articles for Specific Information Test
Sample Item 2

Question: What microprocessors do the 5001 Series Exerciser work with?

Answer: 6800, 6802/6800, 8085, and Z80 microprocessors (page 172).

Enhanced signature analyzers ease μP-system diagnosis

Because most designers don't incorporate field-proven signature analysis into their equipment, new units reflect the needs of test engineers and servicemen instead.

Charles H Small, *Associate Editor*

Although the complexity of bus-oriented digital designs makes system problems harder to diagnose and eliminate than analog circuits, recent signature-analysis introductions make the procedure very easy even for low-skilled technicians. Furthermore, these products help the test engineer to develop signature-analysis troubleshooting schemes for servicemen. And while some signature-analyzer makers contend that signature analysis doesn't have to be designed into a piece of equipment, no one argues against the advantages of built-in testability (see box, "Design for serviceability check list").

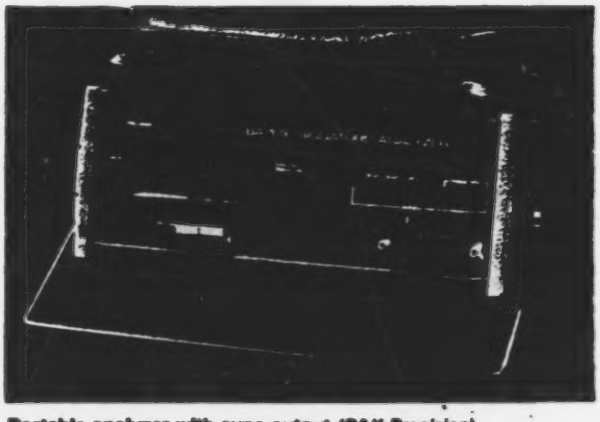
Preaching falls on deaf ears

Introduced by Hewlett-Packard in 1977, signature analysis promised to make the troubleshooting of μP-based products as easy as fixing a TV set. Has this prediction come true? For the most part, yes. But if signature analysis is such an easy and inexpensive way to test complex digital products at system speed (the most expensive field-service signature analyzer costs $2800, the least $395), why haven't equipment designers universally incorporated it into their designs? In reality, signature analysis is a difficult sell, despite continued preaching by test engineers. It suffers especially because it's the one test technique that's of little use to design engineers. Designing in signature analysis takes time, requires careful analysis and affects mechanical, electrical and software designs. Yet all this effort by the design engineer benefits only the serviceman, who might not even work for the engineer's company.

Financial considerations overrule technical

Oddly enough, those companies that are successfully enforcing the discipline of designing in signature analysis are doing so because of a commitment by management rather than engineering. Management's reasons are economic, not technical. While everybody likes to see all segments of the electronics industry make money, there's a subtle but important distinction between designing in testability to maximize the profitability of the service department and designing in testability to manufacture a product more reliably.

By contrast, the inclusion of other forms of testability *can* benefit the entire design team. For example, using



Portable analyzer with sync output (B&K Precision)

TEK 7000 SERIES PLUG-IN SPECTRUM ANALYZERS

From 20 Hz to 5 MHz: The Tek 7L5 Spectrum Analyzer delivers high value, measurement versatility.

VALUE-ADDED ENGINEERING BY TEKTRONIX.

The 7L5 delivers more performance per dollar than you're likely to find in any other baseband spectrum analyzer on the market today. Simplified operation. Synthesized tuning. Excellent frequency accuracy and stability. All in an affordable, versatile plug-in that fits into any 7000 Series mainframe and is exchangeable with over 30 different test and measurement plug-ins. Match growing requirements at a reasonable cost.

ADD UP THE BENEFITS.

Very easy to use, the 7L5 lets you concentrate on answers, not operation. Digital storage and synthesized frequency control mean fewer external controls. Three-knob operation makes set-up a snap. You can set center frequency with six-digit accuracy immediately upon turn-on. Reference level in 1 dB steps.

SEE IT ALL.

The 7L5 covers 20 Hz to 5 MHz in one display, with 10 Hz resolution and no more than 1 Hz residual FM. Comparing baseband channel performance is easy because the 7L5 switches from a single channel to a 60-channel supergroup without retuning. You can see all channel amplitudes at a glance, side by side.

Digital storage provides sharp, flicker-free displays, plus digital averaging and peak detection to measure very low level signals and noise. Its MAX HOLD function makes it possible to track slowly drifting waveforms over long periods of time.

All parameters, including center frequency, are displayed on the CRT for easy referencing and documentation.

FRONT-END FLEXIBILITY.

Probe-compatible input modules accommodate a variety of impedances. The L3 provides switch-selectable 50 ohm, 600 ohm and 1 megohm interface, and the L3-1 offers 75 ohm, 600 ohm and 1 megohm alternatives. Displays are automatically calibrated for the module in use. Utilization of a 013-0182-00 Balanced Input Transformer provides correct matching to balanced loads.

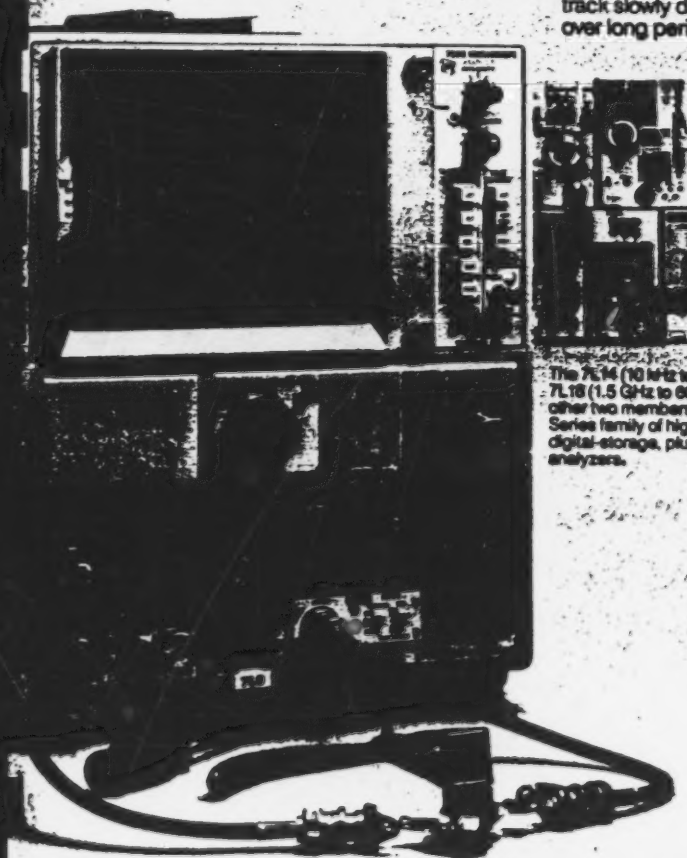
7000 SERIES VERSATILITY IS PART OF THE BARGAIN.

An optional Tracking Generator can be included in your 7L5 plug-in to measure filter shape and make swept frequency tests from 10 Hz to 5 MHz. It requires a third space in a 7000 Series mainframe.

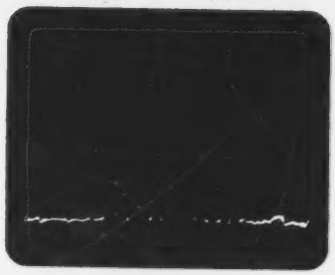
Other 7000 Series Spectrum Analyzer Plug-ins extend your range to 60 GHz. And you can use the same powerful mainframe for logic analyzer, oscilloscope and other measurements. That kind of value is the foundation of the Tektronix plug-in concept.

Contact your nearest Tektronix Field Office (listed in major city directories) for more information. Or call 1-800-547-1512 for descriptive literature. (In Oregon, 1-800-452-1877).

Tektronix, Inc., P.O. Box 1700, Beaverton, OR 97075. In Europe: Tektronix Europe B.V., P.O. Box 827, 1180 AV Amstelveen, The Netherlands.



The 7L14 (10 kHz to 1.8 GHz) and 7L18 (1.5 GHz to 60 GHz) are the other two members in the 7000 Series family of high-performance, digital-storage, plug-in spectrum analyzers.



Amplitude comparison of a 12 channel baseband system

Performance worth the name

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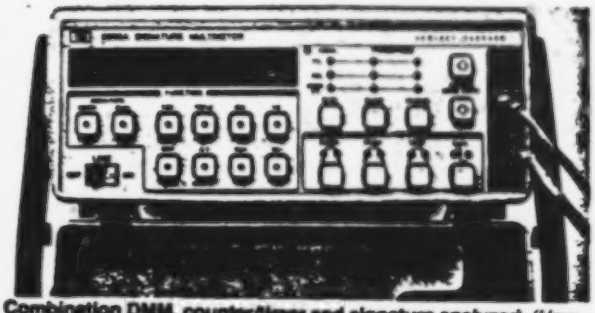
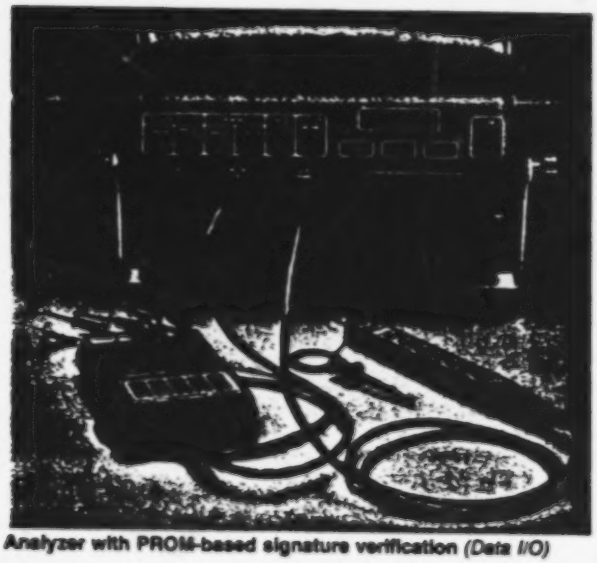
Signature analyzers invade local repair shops



Combination DMM, counter/timer and signature analyzer) *(Hewlett-Packard)*



Analyzer with PROM-based signature verification *(Data I/O)*

board testers to verify and exercise prototypes can speed design throughput enough to more than pay for the testers. What's more, other general-purpose test techniques using such common instruments as DMMs, oscilloscopes or logic analyzers are as applicable to design as to manufacturing and testing.

A tool for test engineers and servicemen

In view of these facts, it's not surprising that recent signature-analysis products are not aimed at the design engineer. Instead, they reflect the needs of test engineers and servicemen. Indeed, with these new devices, test engineers now have system exercisers that take control of a μP-based product so that it produces stable signatures. Furthermore, servicemen don't have to spend as much time taking and comparing signatures, because the analyzers do some of the comparing for them.

These exercisers, however, entail added expense and require that the serviceman carry around another box. To eliminate the need for more pieces of equipment, manufacturers are now incorporating signature analyzers into more conventional testing systems.

For example, HP's first signature analyzer, the $1100 Model 5004A (introduced in 1977), performs no other function. It has two probes: one for capturing node data and another having gate-start, gate-stop, clock and ground leads. Its data probe reguires a 15-nsec setup time and no hold-up time, while gate-start and gate-stop lines need 25 nsec of setup time. The clock input processes 10-MHz max clocks and needs a 50-nsec min clock-pulse width. The unit plugs into the wall and provides front-panel LEDs for start, stop, clock and unstable signatures.

An all-in-one tester

HP's newer $2800 5005A, on the other hand, incorporates the signature-analysis capability of the 5004A along with a 4½-digit DMM and a 50-MHz counter/timer—all elements working through the same probe. The 5005A, therefore, can check asynchronous and analog portions of the system under test that can't be handled with signature analysis. Additionally, its signature analyzer works at clock speeds as high as 25 MHz. The unit's DMM measures dc volts with 1-mV resolution, captures peak voltage to ±12V dc, displays the difference between the probe's voltage and a reference voltage, and measures resistance with 1Ω resolution.

The 5005A's counter shows five digits of frequency or totalized counts with 1-Hz resolution on the 100-kHz range. Its signature-analysis capabilities are similar to the 5004: 10-nec hold-up time on the data probe and 20-nec hold-up on the start and stop lines. In addition to the gate-start and gate-stop lines, the unit has a qualifier line, meeting similar specs, that proves useful for partitioning circuits.

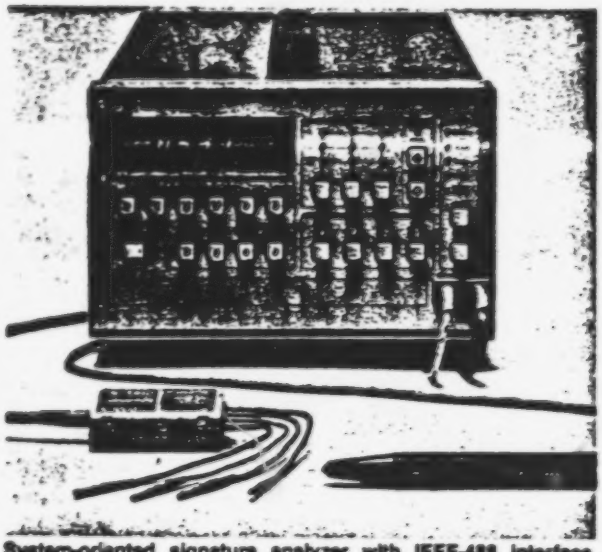
The 5005A can also add up a running checksum of a series of signatures and display it. With this capability, the serviceman can probe a series of nodes rapidly without referring to documentation. If the observed checksum matches the prerecorded checksum, then the serviceman can assume that the entire string of nodes is operating correctly.

Time constraints force board swapping

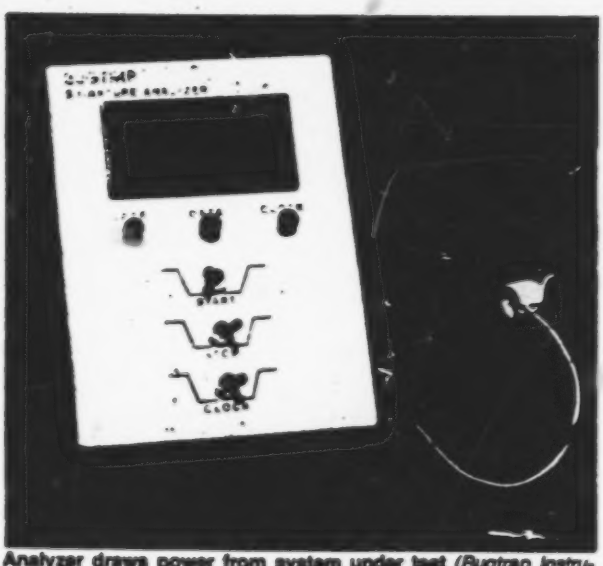
Although signature analysis should theoretically allow a serviceman to repair systems out in the field at the component level, the reality is that many servicemen don't have the time or on-site facilities to do anything more than board-swapping. Noting that signature analysis is popular with ATE makers, it's no surprise that HP offers, in addition to its portable, service-oriented products, some system-oriented units

that are more useful in depots and production.

The $3800 5005B adds an IEEE-488 interface to the 5005A. This means HP can offer the 5005B as part of the $9500 (min) 5505A logic-troubleshooting system. For your money, you get an HP 85 desktop computer and software for computer-aided collection of signatures. The software has menus that guide you step-by-step through your circuit. The software automatically produces fault trees and signature lists. During testing, the software checks signatures against signatures in its database and provides guided backtracing for less experienced troubleshooters.



System-oriented signature analyzer with IEEE-488 interface, DMM, counter/timer and composite-signature capability *(Hewlett-Packard Co)*



Analyzer draws power from system under test *(Bugtrap Instrumentation Inc)*

Exercisers relieve design-in problems

Hewlett-Packard rounds out its signature-analysis products with a line of in-circuit-emulator-like μP exercisers. The 5001 Series exercisers cost $900 to $1075 (depending on the processor) and work with 6800, 6802/6808, 8085 and Z80 μPs. Like the in-circuit emulators they resemble, the exercisers replace the μP in the system under test. Taking control of the μP's bus line, the exercisers can overlay their own internal memory over the system's memory. With these methods, the exercisers run preprogrammed instruction-set, ROM, RAM and I/O-port tests. You can also add your own custom ROM for special tests. Although it's an extra box to carry around, the 5001 Series exerciser circumvents the problem of designing signature analysis into your product.

Unlike HP, Kurz-Kasch has never claimed that signature analysis has to be designed in (other than having the μP in a socket). The firm's $825 Signature II aims squarely at the field-service market and comes with a carrying case that allows the unit to be checked as baggage rather than hand-carried onto an airplane. The firm also makes $45 NOP (null instruction) fixtures and a $225 INOP (intelligent NOP) stimulator that substitutes for common μPs. The INOP has room for eight 256-byte test programs. It comes with standard processor and memory tests, and Kurz-Kasch will write custom programs for other circuit devices.

This particular firm originated the logic probe. And its experience in that field carries over to the design of the signature analyzer's pod and data probe. The pod, which carries the clock, qualifier, start, stop and ground lines, communicates with the instrument over a 68Ω terminated cable to minimize crosstalk. Other signature analyzers simply connect the circuit under test to the instrument via a straight cable rather than buffered pods. Unbuffered probes could unduly load the circuit under test or be susceptible to crosstalk at high frequencies.

The Signature II's data probe displays a repetitive waveform's duty cycle to 100 MHz on a pair of LEDs—just like a logic probe—and has switch-selectable single- or dual-threshold logic sensing. The gate-control inputs work to 50 MHz, and the clock input accepts signals to 25 MHz.

Independent firm builds its own analyzer

While some companies rejected signature analysis after looking at it when it first appeared, Data I/O went one step further. The firm rejected the use of signature analysis in its own products because of implementation

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Applied Microsystems

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difficulties. Reasoning, however, that such difficulties could be overcome with proper instruments, it entered the market for stand-alone signature analyzers. The firm designed its $1995 1310A (IEEE-488 version, $2390) signature analyzer and the $1995 1320A stimulator to work around the design-in problem as well as speed up signature verification.

The 1320A stimulator requires a personality card and a personality pod to adapt it to 8085, Z80, 6800 or 8080 μPs; other companies' stimulators are dedicated to one specific processor. Extra personality sets cost $695. Front-panel thumb switches set high and low limits for memory, making it easy to converge on a defective chip that occupies a segment of the address space and specifies a trigger address. The unit's μP-interface pod can sequentially serialize all eight lines of a bus so that the data probe can take a composite signature rather than eight separate signatures.

The companion 1310A signature analyzer specs a 15-nsec hold-up time for its data probe and 25 nsec for the start-gate, stop-gate, qualifier and clock inputs. The clock accepts signals to 10 MHz. The most distinctive feature of the instrument is a ROM pack that plugs into the front panel and holds as many as 500 signatures captured from a unit known to be operating correctly. During the test, the unit checks signatures

Design for serviceability check list

Taking into account the following field-service considerations at the initial design stage will realize several advantages. Service calls become shorter, redesigns are eliminated, a large amount of equipment is not needed, and the manufacturer and customer see their costs reduced.

- Are inputs and outputs protected from normal abuse?
- Are LEDs used to advantage inside the system to indicate proper operation? For example, a lighted LED could indicate that a phase-locked loop is locked, that the clock is present, that the power-supply voltage is correct, etc.
- Are components located far enough from integrated circuits to allow test clips to be placed on the ICs?
- Can feedback be easily disabled for troubleshooting purposes? A good example would be a jumper wire that can be removed to break feedback between several ICs on a board. Sometimes feedback can be broken by pulling a board in the feedback loop.
- Are display LEDs easy to replace?
- Are there power terminals for logic - probe / pulser/ current-tracer operation?
- Are interconnecting cables long enough to allow operation of boards when placed on extenders?
- Are boards independent? Avoid, if possible, a device on one board and its pull-up resistor on another. If this is necessary for proper line termination, provide on the board a switchable pull-up resistor for stand-alone tests.
- Is it possible to force manually a node to a particular state for troubleshooting purposes?
- Can the system be operated with any of its circuit boards removed, ie, does the power supply require a certain load?
- Are boards keyed so that they cannot be inserted incorrectly?
- Have all three types of troubleshooting documentation techniques been considered? These are:

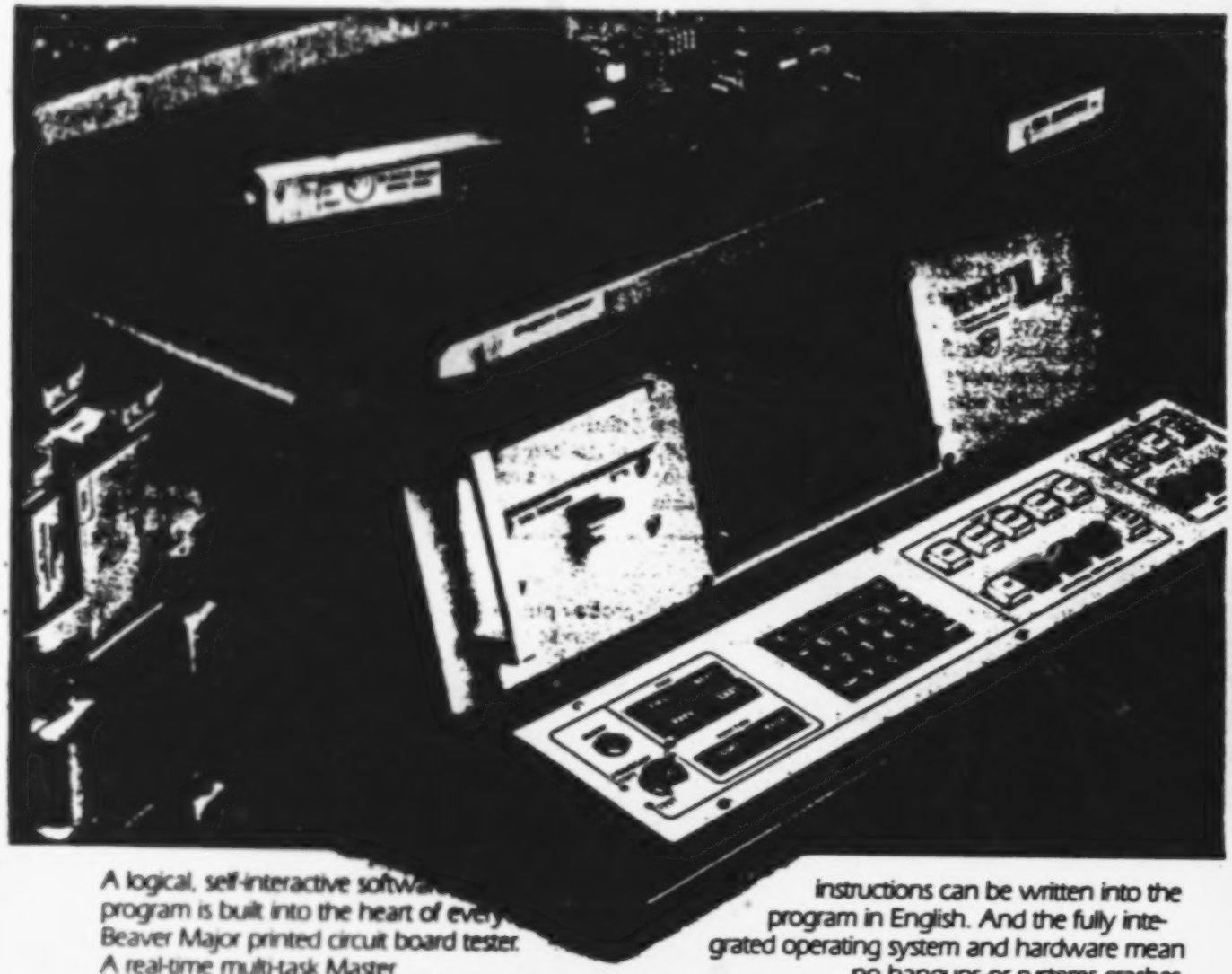
  Symptom cause: List symptoms and possible causes. This technique can be helpful with μPs that can display error codes when a specific failure occurs.

  Troubleshooting tree: Test and branch based on results of test. A good tree requires more development time than any other approach since its developer must convince himself that the person following a fault through the tree will not get lost in a wrong branch.

  Growing the kernel: The system is exercised in a series of operating modes arranged in increasing levels of complexity so that each successive operating mode exercises a larger percentage of the system. By observing the first operating mode in the sequence that fails, it's possible to quickly limit the problem to those assemblies that are used in the failed operating mode but are not used in the previous modes that all passed.

Acknowledgment

We wish to thank Hewlett-Packard Co for providing technical information used to compile this check list.



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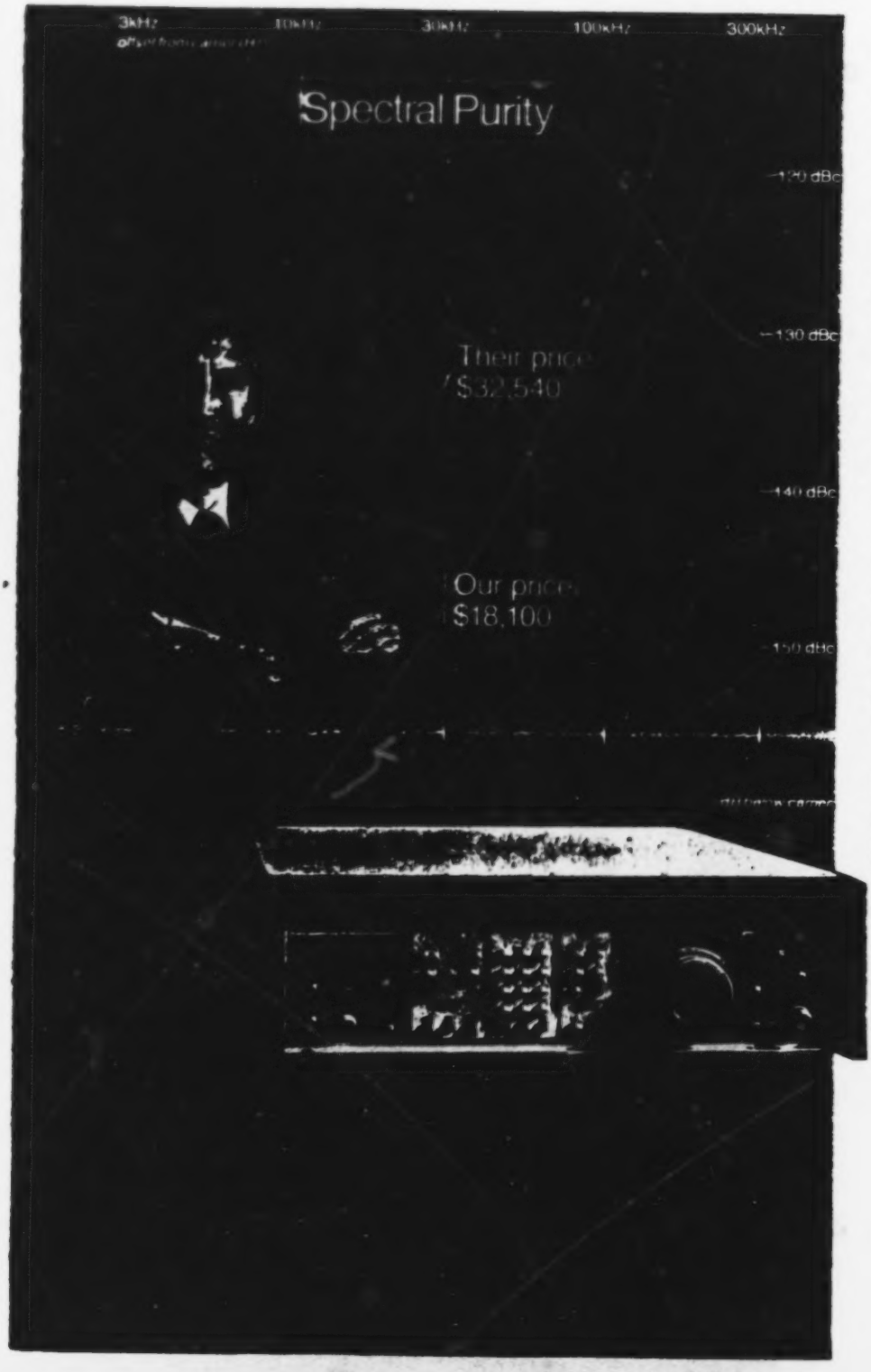

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System stimulators usurp system ROMs

against the list of signatures known to be good and notifies the operator if a mismatch occurs. Note that this technique is not a form of guided-probe testing. The signature analyzer isn't looking for signatures in any particular order; it's just checking to see if a signature from the system under test is on the list.

The analyzer performs transition counting as well as signature analysis. Transition counting sometimes proves useful when checking asynchronous nodes. Note that the HP 5005's counter can do the same thing in totalizer mode. The 1310A also has an optional IEEE-488 interface.

Meanwhile, B&K Precision's $825 Model SA-1010 works with clocks to 20 MHz and requires a 10-nsec setup time for all inputs. Additionally, it has switch-selectable input thresholds for TTL or CMOS logic. It also has logic-probe LEDs for indicating high, low and pulse activity at the observed node. The instrument's unique feature is a 1-MHz output clock for synchronizing circuitry under test.

Simple units suit field service

Two firms make expressly for field service less expensive signature analyzers that have none of the extra features of their competition. The NWS μT1000 costs $479 and uses a 9.2V ac plug-in transformer for power. If your system has an extra 600 mA at 9.2V ac to spare, you won't need the transformer. The instrument accepts clocks to 15 MHz and requires 15-nsec hold-up time on all inputs. It conforms to the original HP signature-analysis spec and has no qualifier line.

Even less expensive at $395, the Bugtrap signature analyzer has no built-in power supply; it draws 400 mA from the system under test. Like the NWS unit, the Bugtrap accepts 15-MHz clocks and performs only basic signature analysis.

Signature analysis affects design process

Just what do you have to do to develop signature-analysis tests for a new design? The simple answer is to incorporate the capability for signature analysis at the design stage. In practice, however, that turns out not to be such a simple answer. To get stable signatures, you need two things: repetitive activity in the circuit to be tested and a predictable gate signal.

Repetitive activity in your circuit presupposes that the circuit is able to do something; in other words, signature analysis won't work if the unit is completely dead. Therefore, adopting signature analysis affects your most basic decision on how to lay out the system. Ideally, the kernel of the system should be entirely on one board and isolated from its peripheral devices. That way, the serviceman can first plug in just the board containing the kernel. After verifying the operation of the kernel, he can work outwards, adding boards to bring the whole system up. Putting the board containing the kernel on an extender equipped with bus- and signal-disable switches can further aid in isolating sections of the system under test.

The kernel comprises the μP and enough ROM, RAM and glue circuitry to run simple test programs. The test programs must execute quickly, exercise the kernel thoroughly, require no initialization and contain no conditional branches.

The routines have to be quick so that the serviceman holding the signature-analysis probe on the node won't become bored or let it slip off. If your system has undefined internal states upon power-up, these uninitialized states could propagate around the kernel and pollute the signature analyzer's residue. And obviously, if the test routines have conditional branches, the software might not take the same path through every pass.

Kernel testing mimics power-up tests

Because testing the kernel generally involves the same procedures as a power-up test, you can save some effort if you give the serviceman access to the power-up routines that test the μP's instruction set, verify the system ROM and perform read/write tests of system RAM. Remember that the serviceman might call up these tests in a different order from the power-up sequence, so none of the routines should depend on initialization done by a previous test.

You might ask why the serviceman needs signature analysis if the unit has built-in power-up tests. Power-up tests usually report their outcomes on some sort of display—a readout or an LED. If the display isn't working, the test is ineffective. Signature analysis, on the other hand, requires a minimal amount of working circuitry. If the ROM's checksum test, for example, simply takes a known amount of time to execute for a good ROM, the serviceman can spot a bad ROM by putting his probe on a steady One and having his analyzer count the number of clock cycles the ROM test takes.

The serviceman can access built-in tests if you make switches used for other functions do double duty. If your product doesn't have suitable built-in tests, you can provide an extra edge connector so that a test ROM can connect to the system bus.

Finding stable gates for memory tests isn't too tough either. Because a memory test steps through all possible addresses, the most significant address line provides a handy gate. One novel technique is to decode a write to a read-only area.

Another way to get a repetitive program running on the kernel is to force the μP to execute NOPs.

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Name _____ Company _____ Address _____ Mail Stop _____ City _____ State _____ Zip _____ Tel. (___) _____

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Designing for testability requires management commitment

Kurz-Kasch's NOP fixtures are placed between the system's μP and its socket. These hard-wired fixtures impress the opcode for a NOP onto the target μP's data pins. This causes the processor to cycle through its entire address space endlessly.

While the NOP fixture has a certain appealing simplicity, it's not the universal solution to the problem of testing the kernel. For one thing, the processor will tread through its entire address space stimulating not just ROM and RAM but all other memory-mapped circuitry. You'll have to disable everything on the address bus except the system ROM to get repeatable stimuli on the data bus. And processors having multiplexed address and data buses don't lend themselves to simple fixturing. The technique is handy, however, for checking address decoders and other circuitry that receives its stimulus from the address bus but doesn't feed back to the data bus.

The primary disadvantage of the NOP fixture—as with a special substitute system ROM used only during testing—is that the device must be physically placed in and removed from the system under test. This, in turn, means the processor, and perhaps the ROM, must be socketed. Socketing reduces reliability, and having the serviceman remove and reinsert components runs the risk of damaging the components or the board.

Asynchronous circuits present problems

After checking the kernel, the serviceman will have to check the peripheral circuits, many of which are asynchronous. There are four basic ways to handle asynchronous circuits with signature analysis: don't design them in to begin with (the null solution), make them synchronous during the signature analysis, test them by themselves using some other technique, or just don't test them. Some digital circuits, such as keyboard encoders, don't lend themselves to signature analysis.

Because interrupts by their nature occur unpredictably, an interrupted process can't yield repeatable signatures. For kernel testing, you'll have to disable interrupts. To test the peripheral circuits, the interrupts must be forced in a predictable manner. One way to force interrupts is to tie the interrupt pin to a line stimulated by the test ROM. Alternatively, extra software in the interrupt handlers can check to see if signature analysis is going on. If not, the handler can service the interrupt. If it is, the program can branch to special routines.

One-shots are a special problem because, as their pulses get longer, they become less and less accurate and therefore less and less likely to remain synchronized with the system's clock. If you can't shorten the one-shot's period for testing purposes, you'll probably have to use some other technique to test it, such as a conventional counter/timer. The same restrictions apply to hybrid digital/analog circuits as well. Unless you can force the analog circuit to look like a digital one—have a D/A converter alternate between 0 and 5V, for example—you'll have to complement signature analysis with other testing methods.

Three-state devices can fool some signature analyzers. The solution here is to employ pull-up resistors or an analyzer with dual-threshold sensing.

Getting your circuit to yield stable signatures is only the first step. Once you get stable, predictable signatures from several examples of your design—not just from one "golden unit"—you'll have to document the signatures. Because a bad signature is only a symptom and not a diagnosis, you'll have to develop troubleshooting guides so that the serviceman can spot the bad component once he finds a bad signature. Furthermore, every time you revise the product you'll have to repeat all the documentation-development steps. EDN

For more information...

For more information on the analyzers and exercisers discussed in this article, contact the following manufacturers directly or circle the appropriate numbers on the Information Retrieval Service card.

B&K Precision
6460 W Cortland St
Chicago, IL 60635
(312) 889-9087
Circle No 700

Bugtrap Instrumentation Inc
1173 Tasman Dr
Sunnyvale, CA 94086
(408) 734-1118
Circle No 701

Data I/O
10525 Willows Rd NE/C-46
Redmond, WA 98052
(206) 881-6444
Circle No 702

Hewlett-Packard Co
1507 Page Mill Rd
Palo Alto, CA 94304
Phone local office
Circle No 703

Kurz-Kasch Inc
Box 1246
Dayton, OH 45401
(513) 299-0990
Circle No 704

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Appendix 5
Reading Practices Inventory (1)

Appendix 5A

Reading Practices Orientation

We are interested in how much reading you do each month in the areas of electronics and engineering. You should think of reading as gaining meaning from written messages. Reading activities should be counted if they are the only thing you are doing; they should also be counted if you are reading while you are doing something else, such as studying or working. Reading may occur for any length of time, from 1 minute to 1 hour or longer. You should include what you read at your place of residence, at your work, for school, and on the non-work days such as weekends and holidays.

People have many purposes for reading. Four of them are 1) gaining knowledge, 2) locating specific information, 3) keeping abreast, and 4) evaluation. For this study, these are defined as follows:

KNOWLEDGE--you read to increase knowledge and to remember a total body of information. For example, you might read an article carefully to understand the causes of inflation and unemployment.

SPECIFIC INFORMATION--you are looking for information embedded in large amounts of print or for a piece of information to satisfy a particular need. Locating the time for the office picnic in a memo is an example.

KEEPING ABREAST--you read to become aware of new ideas, facts, or developments, to learn the gist of topics, to keep up in a field. Looking over an article on the Presidential candidates' campaigning is an example.

EVALUATION--you read to examine and judge written material or to detect errors in, correct, or revise a document. An example is reading a proposal in order to review it and give a formal response about its content.

We want to ask about your reading in the area of electronics and engineering, and how much you read for knowledge, specific information, keeping abreast, and evaluation.

Codes

Frequency	Time
Rarely= 0	1-4min=5
Monthly=1	5-9min=6
Weekly= 2	10-14min=7
2-4x/wk=3	15-29min=8
5x/wk= 4	30-60min=9
	Over 60--specify

Appendix 5B

Reading Practices Inventory (1) in Electronics or Engineering

Codes

Frequency	Time
Rarely= 0	1-4min=5
Monthly=1	5-9min=6
Weekly= 2	10-14min=7
2-4x/wk=3	15-29min=8
5x/wk= 4	30-60min=9
	Over 60--specify

Name: _____
Date: _____
Examiner: _____

Journal Articles

1. How often do you read about electronics and engineering in this type of material for the purpose of gaining knowledge? _____

2. When you do read about electronics and engineering in this material to gain knowledge, how much time do you spend with it? _____

3. How often do you read about electronics and engineering in this type of material to locate specific information? _____

4. When you do read about electronics and engineering in this material to locate specific information, how much time do you spend with it? _____

5. How often do you read about electronics and engineering in this type of material for the purpose of keeping abreast? _____

6. When you do read about electronics and engineering in this material to keep abreast, how much time do you spend with it? _____

7. How often do you read about electronics and engineering in this type of material for the purpose of evaluation? _____

8. When you do read about electronics and engineering in this material for evaluation, how much time do you spend with it? _____

Schematics

9. How often do you look at this type of material to gain knowledge? _____

10. When you do look at this material to gain knowledge, how much time do you spend with it? _____

11. How often do you look at this type of material to locate specific information? _____

12. When you do look at this material to locate specific information, how much time do you spend with it? _____

Codes

Frequency	Time
Rarely= 0	1-4min=5
Monthly=1	5-9min=6
Weekly= 2	10-14min=7
2-4x/wk=3	15-29min=8
5x/wk= 4	30-60min=9
	Over 60--specify

Schematics

13. How often do you look at this type of material for the purpose of keeping abreast? _____

14. When you do look at this material to keep abreast, how much time do you spend with it? _____

15. How often do you look at this type of material for the purpose of evaluation? _____

16. When you do look at this material for evaluation, how much time do you spend with it? _____

Manuals

17. How often do you read about electronics and engineering in this type of material for the purpose of gaining knowledge? _____

18. When you do read about electronics and engineering in this material to gain knowledge, how much time do you spend with it? _____

19. How often do you read about electronics and engineering in this type of material to locate specific information? _____

20. When you do read about electronics and engineering in this material to locate specific information, how much time do you spend with it? _____

21. How often do you read about electronics and engineering in this type of material for the purpose of keeping abreast? _____

22. When you do read about electronics and engineering in this material to keep abreast, how much time do you spend with it? _____

23. How often do you read about electronics and engineering in this type of material for the purpose of evaluation? _____

24. When you do read about electronics and engineering in this material for evaluation, how much time do you spend with it? _____

Appendix 6
Text Search Process Form

Appendix 6

Text Search Process Form

Observation Schedule
Process of Text Search

Question____

_____Look at contents table

_____Look at index

_____Turn to page designated by Table

_____Read second contents Table

_____Scan article for headings (page through)

_____Read paragraph looking for answer

_____Compare two sections of material

_____Look at the end of the article (manual)

_____Refer to question on test

_____Write answer

_____
_____

Question____

_____Look at contents table

_____Look at index

_____Turn to page designated by Table

_____Read second contents Table

_____Scan article for headings (page through)

_____Read paragraph looking for answer

_____Compare two sections of material

_____Look at the end of the article (manual)

_____Refer to question on test

_____Write answer